NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

THE EFFECT OF PRESENCE ON THE ABILITY TO ACQUIRE SPATIAL KNOWLEDGE IN VIRTUAL ENVIRONMENTS

by

David Bernatovich

September 1999

Thesis Advisor:	Rudolph P Darken
Co-Thesis Advisor:	John S. Falby

Approved for public release; distribution is unlimited.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	September 1999	Master's Thesis

4. TITLE AND SUBTITLE
THE EFFECT OF PRESENCE ON THE ABILITY TO ACQUIRE SPATIAL KNOWLEDGE IN VIRTUAL ENVIRONMENTS

5. FUNDING NUMBERS

6. AUTHOR(S)
Bernatovich, David

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Postgraduate School
Monterey, CA 93943-5000

8.PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

ABSTRACT *(maximum 200 words)*

It is unclear what impact presence has on a virtual environment's (VE) ability to enhance learning and performance. Currently, there are many theories and conjectures about the effects of presence in VEs. To better the effectiveness of VEs, it is imperative that we determine the impact, both positive and negative, of presence on our ability to perform in VEs. Therefore, we must study how presence affects a person' ability to acquire skills and knowledge. This must include our ability to navigate and perform spatial tasks as well as any other aspect of the real world that may be represented by a VE.

To begin understanding how presence affects performance, forty individuals participated in an experiment to determine how presence affects the ability to acquire spatial knowledge in a VE. The purpose of the experiment was to determine if the level of presence in a VE increased or decreased a person's ability to acquire spatial knowledge, to include landmark recognition, procedural knowledge, and survey knowledge. Each participant received one of the following VE treatments: (1) No Sound, (2) Verbal cues with topical information, (3) Verbal cues with spatial information, or (4) a Combination of both topical and spatial information. They were then adminsitered a series of spatial tests. Finally, they were given a presence questionnaire to measure their self-assessed level of presence.

The results indicate that as the level of presence in the VE varies, there is no effect on a person's ability to acquire spatial knowledge. A person's spatial performance is more likely the result of their innate spatial abilities and visual memory. Additionally, including non-spatialized sound in a VE increased the reported level of presence by 15.1 percent. When that sound was exclusively related to the primary task the level of presence increased by 17 percent. Finally, the inclusion of non-spatialized sound has no affect on the ability to perform spatial tasks.

14. SUBJECT TERMS
Virtual Environments, Training, Presence, Spatial Knowledge

15. NUMBER OF PAGES
125

16. PRICE CODE

17.SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFI- CATION OF ABSTRACT	20.LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

This page intentionally left blank.

Approved for public release; distribution is unlimited

THE EFFECT OF PRESENCE ON THE ABILITY TO ACQUIRE SPATIAL KNOWLEDGE IN VIRTUAL ENVIRONMENTS

David Bernatovich
Captain, United States Marine Corps
B.S., Pennsylvania State University, 1990

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN COMPUTER SCIENCE

from the

NAVAL POSTGRADUATE SCHOOL
September 1999

Author: ______________________
David Bernatovich

Approved by: ______________________
Rudolph P. Darken, Thesis Advisor

____
John S. Falby, Co-Thesis Advisor

____
Dan Boger, Chairman
Department of Computer Science

This page intentionally left blank

ABSTRACT

It is unclear what impact presence has on a virtual environment's (VE) ability to enhance learning and performance. Currently, there are many theories and conjectures about the effects of presence in VEs. To better the effectiveness of VEs, it is imperative that we determine the impact, both positive and negative, of presence on our ability to perform in VEs. Therefore, we must study how presence affects a person' ability to acquire skills and knowledge. This must include our ability to navigate and perform spatial tasks as well as any other aspect of the real world that may be represented by a VE.

To begin understanding how presence affects performance, forty individuals participated in an experiment to determine how presence affects the ability to acquire spatial knowledge in a VE. The purpose of the experiment was to determine if the level of presence in a VE increased or decreased a person's ability to acquire spatial knowledge, to include landmark recognition, procedural knowledge, and survey knowledge. Each participant received one of the following VE treatments: (1) No Sound, (2) Verbal cues with topical information, (3) Verbal cues with spatial information, or (4) A combination of both topical and spatial information. They were administered a series of spatial tests. Finally, they were given a presence questionnaire to measure their self-assessed level of presence.

The results indicate that as the level of presence in the VE varies, there is no effect on a person's ability to acquire spatial knowledge. A person's spatial performance is more likely the result of their innate spatial abilities and visual memory. Additionally, including non-spatialized sound in a VE increased the reported level of presence by 15.1 percent. When that sound was exclusively related to the primary task the level of presence increased by 17 percent. Finally, the inclusion of non-spatialized sound has no affect on the ability to perform spatial tasks.

This page intentionally left blank.

TABLE OF CONTENTS

LIST OF FIGURES

This page intentionally left blank.

LIST OF TABLES

This page intentionally left blank.

I. INTRODUCTION

Over the past several years, virtual environments (VE) have become widely accepted as a means of training. The Department of Defense has invested billions in its attempt to save dollars as well as improve training methods for its members. Every year the parade of new and innovative VEs grows. However, despite this increasing acceptance of this new technology, there remain many aspects of VEs which have received little or no attention.

A common underlying assumption has been that VEs are a suitable means or replacement for actual training. This attitude continues to persist even as research demonstrates the potential negative aspects of some VEs. Questions about the suitability of VEs still remain. For example, while conducting a land navigation experiment, Goerger [GOER 98] found that subjects using only a map gained more spatial knowledge of a one km piece of terrain than did subjects using the map and a VE. It is becoming increasingly imperative that the limitations of VEs as training aids be examined in depth.

At this time, the critical components of VEs that are important to training effectiveness are not understood. The overarching goal is to determine what these components are and how each one relates to increased effectiveness of VE training. This will lead to the development of VEs that enhance training as well as eliminate those VEs that inhibit, or are not an effective means of, training and learning.

A. PRESENCE IN VIRTUAL ENVIRONMENTS

One aspect of the subjective experience in VE systems that has received considerable attention is the extent to which the human operator loses his awareness of being present at the site of the interface and instead feels present in

the artificial environment. This feature is often referred to under the headings of tele-presence, virtual presence, or synthetic presence and is dependant on *__many factors__*, *including (but not limited to) the extent to which the interface is transparent and attenuates stimulation from the immediate environment, as well as the amounts and kinds of interaction that take place in the artificial environment.*

[DURL 95]

Attempting to identify all the critical components of VEs is difficult, however there are certain components that are almost universally accepted. One of these components is presence. Presence can be described as the psychological sense of "being there." In other words, it is the ability to be in a place (VE) other than where one's body is physically located. What makes VEs so unique is not only the ability to create these worlds so that we can visit and interact with them in ways not possible only a few years ago, but also the phenomenon of presence. Presence is often considered a central goal of VEs, perhaps a defining feature [STER 92]. This sense of presence can occur while reading a book or watching television, however these media do not stimulate the senses in the same manner as a VE. VE technology enables a direct first-person experience to a much greater degree than any previous medium [DODS 98].

One of the major problems when studying presence is the myriad of definitions that exist as well as the subjective nature of its measurement. Although few would argue that presence does not exist, it is loosely defined. This fact often leads researchers to proceed in the absence of a universal definition. This has resulted in even greater ambiguity as to what presence actually is as well as what presence is not. Often the terms presence and immersion are used interchangeably when discussing the utility of VEs. However, immersion relates to the technologies used to create VEs while presence involves the cognitive response or sense of

"being there" [SLAT 97]. There is little hard evidence to define the relationship between the two, but it would seem obvious that some relationship must exist. Past research has shown that technological factors that have affected the level of immersion also have had an affect on the level of presence. What is now needed is a systematic research effort designed to gain an understanding of the cognitive and technological factors that determine the sense of presence as well as the influence of presence on general learning, task performance, and knowledge acquisition within VEs (Figure 1).

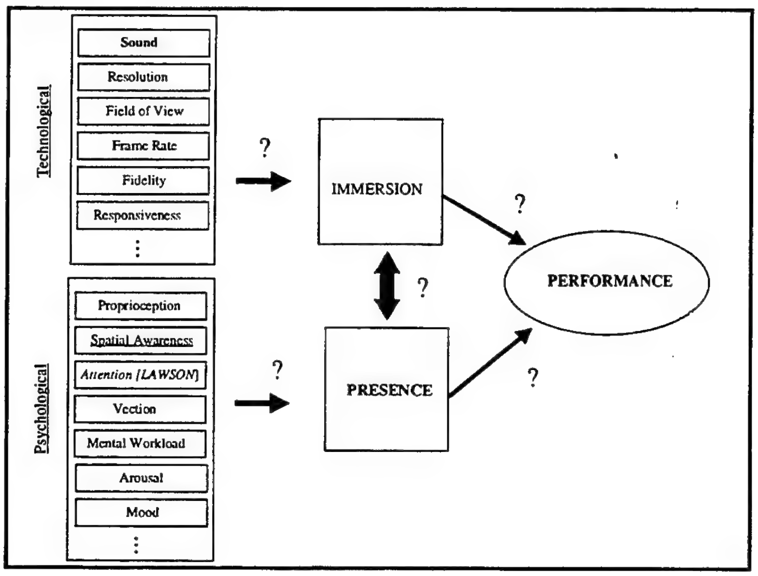


Figure 1: Influencing Factors of Presence and Immersion

The goal of this research is not to develop a clear and unambiguous definition of presence nor to establish a comprehensive relationship with immersion, but rather towards an understanding of the effects of presence as well as its components and to relate these to performance in VEs. If this can successfully be done, a body of knowledge will then exist for the design of VEs that effectively use presence for training or whatever their intended purpose.

B. PRESENCE AND PERFORMANCE

The phenomenon of presence is being used as the basis for predicting new gains in the effectiveness of learning, comprehension, performance, and transfer of training [SHER 92]. These claims are consistently made despite a lack of evidence. This comes from the belief that training in a VE provides convincing practice for reactions that occur in the real environment. Therefore, if one believes they are present in an alternate environment or one experiences a higher sense of presence in the VE, the more likely they are to respond to situations in the VE in a manner similar to how they would respond to the same situation if encountered in the real world. However, this is purely conjecture.

The effects of presence on performance are not fully understood in any way nor has a correlation between presence and performance been established. Although the idea that presence will result in better performance seems logical, it is likely that it only plays a supporting role that only enhances performance in specific types of VEs or tasks. From military training to architectural design to surgical simulation, VEs are being used in various ways. From such diverse applications, it is easy to determine that presence likely affects performance to varying degrees among these VEs. Creating VEs that will enhance performance requires knowledge of the types of tasks that are improved with increasing levels of presence.

In the past, traditional psychological explanations were used to describe behavior and performance in VEs. Rarely was the effect of presence measured or taken into account. When a subject performs poorly in a VE experience, is this due to the VE, the interface, or the fact that the user did not feel a significant level of presence? To begin answering this question, it is critical to examine presence as a function of performance of specific tasks within VEs.

One critical part of VEs involves the concept of "space" and in providing the user the ability to acquire spatial knowledge of that space. Lawson (1998) made several observations related to this while conducting his experiment, which was designed to develop a quantitative measurement of presence based on attention theory. These observations are quite relevant when discussing the effect presence has on performance. First, Lawson's experiment positively correlated presence and sound, with sound being defined as non-spatialized verbal cues or ambient noise. These results are not surprising since involving more of a person's sensory modalities should lead to a greater sense of presence. However, this leads to the question of what type of sound is required to increase the level of presence. Is it simply background noise such as that of a car's engine or does it require semantic information such as instructions or verbal cues that direct the users attention to the VE?

Second, those participants whose VE experience included sound reported conclusively that the visual aspects of the VE involved them more completely than the participants who did not receive sound. Further, the participants who received sound during their VE experience conclusively reported a higher sense of objects moving through space as well as a higher ability to examine objects more closely and from multiple viewpoints. Additionally, participants receiving sound believed their ability to control events within the VE was higher than those participants who did not receive sound, although in this case the results were inconclusive. The critical point is that both treatments provided *exactly the same* visual treatment and interface as well as no control over events within the VE. Why does the inclusion of sound result in this perception and what role does presence play in accounting for this perception?

Third, Lawson presents anecdotal evidence to suggest that spatial awareness varied among treatments, although this was not fully investigated. It is logical to suggest that if users

feel more present within a VE, it is more likely that they will be spatially aware of that environment, at least in the same way we are spatially aware of the physical environment. Therefore, it is reasonable to suggest that presence must have played some role in participant's spatial awareness.

However, the presence or absence of sound, particularly non-spatial sound used by Lawson, does not obviously influence the ability to acquire spatial knowledge. Based on these two ideas, the following question arises. If including sound in a VE increases the reported level of presence, and increasing the level of presence increases the level of spatial awareness, does it follow that increasing sound leads to an increase in spatial awareness? Although this argument makes sense on the surface, it is counterintuitive to conclude that sound, in and of itself, would affect a person's ability to acquire spatial knowledge, particularly when the sound is not spatialized nor does it contain spatial content. However, should this argument be proven, does the type of sound in the VE impact presence and thereby impact the ability to acquire spatial knowledge?

Although Lawson's data did not correlate presence and performance, namely spatial comprehension, it does provide an excellent starting point for examining the relationship between sound, presence, and spatial comprehension. This thesis will focus on the effect that non-spatialized sound (i.e. primarily verbal) has on presence and the ability to acquire spatial knowledge within a VE.

C. RESEARCH OBJECTIVES

The primary focus of this thesis is to determine if there exists a correlation between spatial comprehension and presence based on varying aural parameters. This thesis limits its

focus to one real-time VE. The levels of presence provided by varying aural display parameters are identified. To accomplish this goal, an experiment was conducted which will be described in detail later in this thesis. The following questions are examined to better understand the relationship between presence and the acquisition of spatial knowledge.

- Do varying levels of presence affect the amount of spatial knowledge acquired in VEs?
- Does the introduction of non-spatial sound cues increase the level of presence?
- Does the type of sound cue, whether topical or spatial in nature, affect the level of presence?
- What role does innate spatial ability play in the acquisition of spatial knowledge in VEs?

D. THESIS ORGANIZATION

This thesis is organized into the following chapters:

- Chapter I: Introduction. This chapter provides a general framework for the thesis. It discusses the importance of evaluating presence and performance. Additionally, this chapter covers the thesis objectives and the reasons this research is being pursued.

- Chapter II: Background. This chapter looks at both past and present work that are related to both presence and the acquisition of spatial knowledge.

- Chapter III: Approach. This chapter explains in detail how the measures for acquiring spatial knowledge were developed. In addition, it describes the variables that affect the level of presence and how that relates to the level of spatial knowledge acquired.

- Chapter IV: Method. This chapter describes in detail the experiment and different treatments that were administered to each subject group.

- Chapter V: Analysis. Included in this chapter are the results of the experiment in terms of the stated hypotheses.

- Chapter VI: Conclusions and Recommendations. The chapter provides an overview of the experiment results as well as the importance of those results. Finally, it also provides recommendations for future work in this area of research.

- Appendices:
  A. Raw Data
  B. Experiment Outline
  C. In-Briefing Script

D. Consent Forms
E. Questionnaires

II. BACKGROUND

Many conjectures and ideas exist to suggest that an increase in presence is predictive of, or somehow related to, performance within a VE, in spite of the nonexistence of definitive evidence. The reason for this is that presence is a very subjective area of research and a formal definition has not yet been determined. Furthermore, presence is often confused with immersion. In general, research focuses on immersion (technology) and theories concerning presence are merely a byproduct of this research. Currently, there is no widely accepted definition of presence nor has a correlation with performance ever been established.

Why is it important to define presence and determine its effects on performance? First, VE designers are continually developing new and innovative VEs that have extended the limits of VEs. With these new VEs, the ability to create a sense of presence for users seems to grow, yet no one understands the impact presence has on VE performance. If an understanding of presence existed along with its relationship to performance, the efforts of VE designers could be directed at enhancing presence to maximize VE performance, if a correlation does, in fact, exist. Today, most VE designers simply attempt to get maximum frame rates, better fidelity, and improve interfaces assuming that greater realism results in greater presence which results in improved performance. However, how these technological improvements affect presence goes unexamined. Perhaps these improvements are not necessary to improve performance. Perhaps presence has a value in and of itself, outside the scope of performance. These are issues demanding investigation.

In order to better understand the concept of presence and the acquisition of spatial knowledge and how it can benefit the design of VEs, a brief background is presented in the

following areas: presence, spatial knowledge, and methods of measurement of spatial knowledge.

A. PRESENCE

Presence is generally defined as the subjective experience of being in one place when one is physically in another [WITM 98]. Presence implies that observers perceive their self-orientation and self-location with respect to the environment [PROT 94]. Since presence is a perception, it is extremely subjective by nature and difficult to quantify, however it is generally regarded as a defining characteristic of VEs. The Presence Questionnaire (PQ) developed by Witmer and Singer [WITM 98] does provide a means of measuring this subjective perception that users feel in a VE. The PQ is a self-assessment of the level of presence experienced in a VE.

As stated earlier, defining presence is difficult due to its subjective nature. However, Heeter [HEET 92] has presented a framework for defining presence based on three dimensions of presence; personal, social, and environmental presence.

1. Personal Presence

Personal presence refers to the reasons that one feels like they are in another world. Personal presence is affected by seeing one's hand in the VE or even experiencing a sense of deja vu. Research in this area largely focuses on identifying as many features of the VE that contribute to convincing someone that they are in another world. However, it must relate to the VE not the technology used to create that VE since that would be more related to immersion rather than presence.

2. Social Presence

Social presence can be thought of as a subset of personal presence. Social presence deals with other beings that exist in the VE and their reaction to the user. They may be other humans or animated characters that interact with the user. What defines something as contributing to social presence is the fact that someone or something else appears to react to your being there. This perception allows one to more easily accept the fact that they too are there (in the VE).

3. Environmental Presence

Environmental presence is similar to social presence except that instead of someone else reacting to you, the environment itself reacts. For example, if the lights in a room turn on when you enter, or the door closes behind you after you have entered this would enhance environmental presence. Additionally, environmental presence is increased if the objects within the VE behave in a manner consistent with the real world. The ability to walk through walls would be thought to diminish the sense of environmental presence, although there may be benefits associated with this ability.

What these three "dimensions" of presence have in common is that there is something that enables one to believe that they are in another place. The examples mentioned above are visual in nature, however they may likely be in the form of sound or touch. Further, they deal with the realism of the VE. Realism can be defined as how accurate the objects, events, and people are reproduced in the VE. If the VE is more accurately depicted (with respect to realism) then the level of presence should increase.

These dimensions provide an excellent starting point to understanding the types of presence that occur within VEs. What is most interesting about these dimensions, and the literature as well, is that presence is almost universally explained from an egocentric point of

view. Presence from an exocentric point of view is rarely discussed and little research exists that compares egocentric versus exocentric frames of reference in terms of presence. However, since the literature discusses the importance of realism as a factor for increasing levels of presence, egocentric frames of reference, which are more "real" than an exocentric frame of reference, can be thought of as producing higher levels of presence.

B. IMPACT OF PRESENCE ON PERFORMANCE

Presence frequently becomes an issue because it is thought to correlate with task performance, however there are many factors that alter the level of presence, thus attempting to speculate its effects is difficult. Irregardless, there remains the question of how presence contributes to task performance in VEs.

Presence is important because the greater the degree of presence, the greater the chance the participant will behave in a VE in a manner similar to their behavior in similar circumstances in everyday reality [SLAT 97]. From this, we can see the implications of studying presence. If presence creates behavior in a VE that we would expect in the real world, it follows that presence may also affect performance or the ability to learn in a VE consistent with that of the real world. If this were the case, it would enable developers of VEs to enhance learning based on the proven concepts of learning in the real world.

Presence implies that observers perceive their self-orientation and self-location with respect to the environment [PROT 94]. Assuming this is the case, an argument can be made that acquiring egocentric spatial knowledge of an environment requires a sense of presence. In a VE, presence is closely linked to situational awareness. Prothero [PROT 94] suggests these are overlapping constructs. If one is situationally aware, then one should acquire spatial knowledge

of that environment. However, to date no relationship exists between presence and spatial knowledge acquisition.

C. SPATIAL KNOWLEDGE

There has been considerable research done on the psychological aspect of acquiring spatial knowledge. Spatial knowledge or spatial cognition is a mental representation of a real or virtual emvironment [WICK 97]. Thorndyke [THOR 80] breaks spatial knowledge down hierarchically into three levels. They are landmark knowledge, route knowledge, and survey knowledge (Figure 1). It should be pointed out that each level is not self-inclusive, but rather builds upon the knowledge gained at the previous levels [THOR 80]. To measure the amount of spatial knowledge acquired, all three must be taken into account.

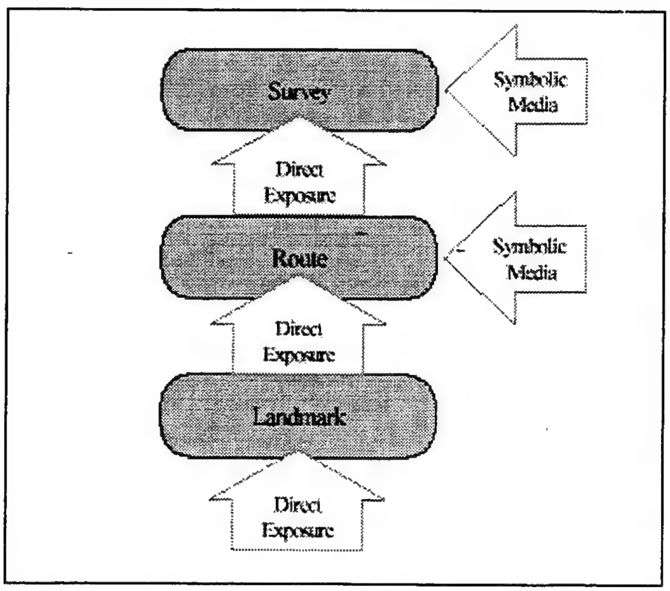


Figure 2: Thorndyke's Hierarchical Model

1. Landmark Knowledge

Landmark knowledge is static information about the visual details of a specific location [DARK 95]. This implies that measuring landmark knowledge is based on a person's ability to recall objects they have seen, such as road intersections, terrain features, or buildings. Satalich [SATA 95] explains that objects become landmarks for two reasons: their distinctiveness and personal meaning. It is a visual task that largely depends on the capabilities of memory.

The acquisition of landmark knowledge is gained from direct exposure to an environment, however past studies have demonstrated that video and photographs can also provide a person with landmark knowledge. Gale [GALE 90] found that the ability to identify landmarks was identical between those who physically explored an environment and those who were provided a video walk-through. This also suggests that landmark knowledge is gained from an egocentric frame of reference. Figure 3 depicts how landmark knowledge is mentally represented.

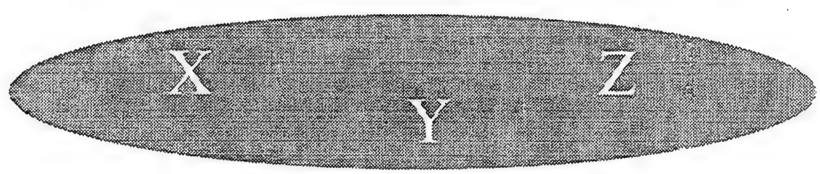


Figure 3: Landmark Knowledge

A person with landmark knowledge can recall any of the distinct features (X, Y, and Z) of this environment, but they would not be able to determine the relative position of these objects nor have the ability to navigate between them. For example, most people who have never visited New York City can easily identify the Statue of Liberty, the Empire State Building, and the Brooklyn Bridge, however if asked to navigate from one to the other or determine their relative

positions they would not be able to do so. To accomplish this task, higher levels of spatial knowledge are required.

2. Route Knowledge

Route Knowledge is defined as the procedural knowledge required to successfully traverse distances between origins and destinations [GOLL 91]. In addition, route knowledge is the ability to navigate successfully from one landmark to another on a known route, but not recognizing alternative routes [SATA 95]. Therefore, route knowledge connects landmark knowledge into a larger, more complex structure [GOLL 91] (Figure 4).

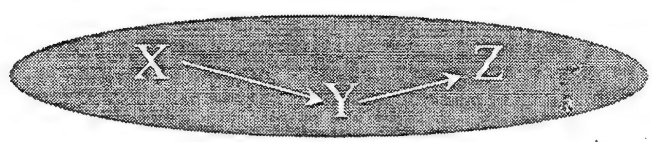


Figure 4: Route Knowledge

Route knowledge can be thought of as memorizing directions in an unfamiliar city. Therefore, route knowledge may be stored as a schema, again suggesting that the ability to acquire route knowledge is memory dependent. Route knowledge is based on approximating distances and landmark knowledge. As with landmark knowledge, acquiring route knowledge is dependent on visual memory. While forming route knowledge, images and landmarks are recalled [SATA 95]. Darken [DARK 95] defines route knowledge as a sequence of actions required to follow a specific route. Figure 4 demonstrates how route knowledge is used to navigate an environment. If a person has to navigate from position X to position Z, the person can only do so along the known route depicted by the solid lines. If, as in figure 5, the route from position X to position Y is blocked, a person with only route knowledge would not be able

to identify the alternate path from position X directly to position Z which is depicted by the dotted line. To accomplish this task, a higher level of spatial knowledge is required.

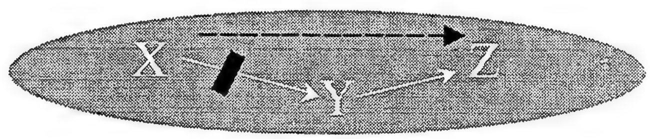


Figure 5: Route Knowledge (with Alternate Route)

3. Survey Knowledge

Survey knowledge is the highest level of spatial knowledge [THOR 80]. Survey knowledge is map-like in nature [DARK 95]. It can be described in terms of route knowledge with the difference being that alternative routes can be identified. A distinguishing feature regarding survey knowledge is that it requires a person to think from an exocentric point of view, whereas landmark and procedural knowledge can be thought of from either an egocentric or exocentric viewpoint. Object location and inter-object distances are encoded in terms of an exocentric, fixed frame of reference which is significantly different from route knowledge which is defined as the sequence of actions required to follow a predetermined route [DARK 95].

Survey knowledge can be gained from map study or through extensive and repeated exposures to an environment [THOR 80]. Acquisition via repeated exposures to an environment suggests that a person also has acquired landmark and procedural knowledge and used this knowledge as a building block to gain survey knowledge. Survey knowledge is demonstrated by an individual's ability to identify known locations and distances between landmarks and having

the ability to devise new routes between these landmarks, even though the individual has never traveled the route between them [BANK 90]. Figure 6 shows how a person with survey knowledge understands the environment. A person can navigate to any landmark as well as identify the relative position of any landmark in the environment regardless of the person's relative position in that environment.

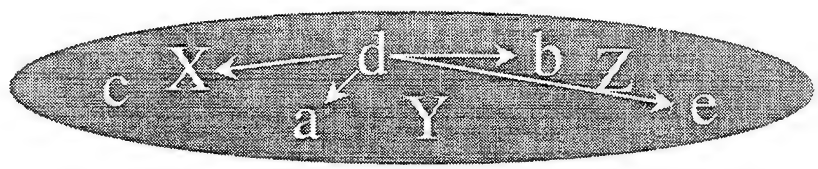


Figure 6: Survey Knowledge

4. Measuring Spatial Knowledge

The study of human spatial cognition cannot be separated from a careful examination of the measures used to assess it [WALL 99]. There are many methods usd to study and evaluate spatial knowledge. This is, in large part, due to the fact that spatial behavior is so varied. Distance estimation tasks and landmark identification are both spatial tasks, however the ways one completes each of these tasks do vary. Clearly, the methods used to measure the various types of spatial knowledge must differ as well.

Methods used to measure landmark knowledge are the most accepted and often used. The methods consist almost exclusively of landmark recognition and recall tests. The reason these tests are so well accepted is the fact that they are easily measured and quantified. Further, how one acquires landmark knowledge varies although the results do not. Gale [GALE 90] found that landmark recognition was identical between groups that physically explored an

environment or those that received a video walk-through. Other research has found that landmark identification could be accomplished via photographs. This indicates that one need not be present or even feel present in an environment to acquire landmark knowledge.

Generally, route knowledge is measured via route replication tasks. Based on the number of wrong turns taken by a participant, the amount of route knowledge can be computed. However, there are many other tests used to measure route knowledge. They include route distance estimation tasks, map sketching tasks, verbal descriptions of routes, route recognition tasks, and landmark sequencing tasks. Although there are benefits for using any of these tasks, there are shortfalls. Map sketching tasks are generally limited by the artistic and motor skills of individuals. Therefore, it becomes difficult to determine if a person performs poorly due to the fact that little route knowledge was acquired or simply that the person is unable to competently sketch a map.

The same problems that exist for map sketching tasks also exist for using verbal descriptions to measure route knowledge. Landmark sequencing tasks are heavily weighted toward visual memory. If a person forgets a landmark, it can greatly affect the route regardless of the amount of route knowledge acquired. Additionally, unlike landmark knowledge, the means of providing information affect the acquisition of route knowledge. The field of view and the ability to selectively attend to the environment both affect the acquisition of route knowledge. Gale [GALE 90] conducted research that compared the amount of route knowledge between individuals who physically explored an environment and those who were provided a video walk-through. The video group performed much worse on the route knowledge tasks. The results were, in large part, due to the fact that the video group was unable to perform head rotations and unable to see objects outside their field of view. These problems must be

addressed in order to fully understand how route knowledge is encoded. Understandably, the methods for measuring route knowledge are less accepted than those used to measure landmark knowledge.

Survey knowledge, like route knowledge, has many methods for measurement and even more shortcomings. Methods used to measure survey knowledge include analyzing map sketches, recognition tests, pointing tests, and Euclidean distance estimation tasks. Generally, the most accepted measures are pointing tasks and Euclidean distance estimation tasks. The Euclidean distance estimation task involves the subject providing distances between landmarks or between landmarks and oneself. The distance is measured "as the crow flies" or simply a straight-line measurement. Pointing tasks have the subject point in the direction of various landmarks in the environment that are outside the field of view or visually obstructed. The major difference between these tasks is the frame of reference. Pointing tasks are almost exclusively measured from an egocentric frame of reference while the Euclidean distance estimation task may be from either an egocentric or exocentric frame of reference. The major shortcoming with both of these tests is that they are largely dependent on a person's spatial abilities. All measures of survey knowledge must take into account the innate spatial abilities of the subjects. This fact makes it difficult to determine if the results are due to the spatial abilities of the subjects or the lack of survey knowledge acquired. In addition, the pointing tasks have the added problem of forcing the individual to make mental rotations. Since survey knowledge is encoded in an exocentric frame of reference, individuals must convert this information into an egocentric frame of reference to complete the task. Mental rotations require a unique skill that greatly varies among individuals. This fact results in innate spatial abilities again playing a significant role in the amount of survey knowledge acquired.

This page intentionally left blank.

III. APPROACH

The purpose of this chapter is to explain the rationale used to arrive at the hypotheses for this thesis. The idea for this research was derived from the results of Lawson [LAWS 98], which found that including non-spatialized sound led to increased immersion and that as immersion increased the corresponding measure of presence also increased. Further, Lawson also suggests that there may exist a link between presence and performance; however, evidence for this was not presented in his research. It is the purpose of this thesis to examine this relationship by first determining if including various non-spatialized sounds can lead to greater levels of presence and then relate the level of presence to performance, which in this case will be the completion of a spatial task. This research question was arrived at via a circuitous route. This experiment takes the approach that if presence is positively correlated with performance of spatial tasks, and sound cues are shown to increase presence, then spatial performance can be correlated with sound cues. If this can be proven, then it seems likely that an associative relationship should exist between sound, presence and performance. However, a connection has yet to be made between performance on spatial tasks, such as navigation and presence.

A. RELATING SOUND AND PRESENCE

The literature suggests that performance on spatial orientation and navigational tasks is likely to be enhanced if the perceived level of presence is increased. In other words, if we really felt like we were in a virtual world, performance on spatial tasks within that world should improve. Also, the past studies of Gilkey [GILK 95] and Hendrix [HEND 96] suggest that aural stimuli are necessary factors in increasing the level of presence in VEs. In addition, Lawson

[LAWS 98] found that including sound in his VE display lead to an increased level of engagement within that VE.

Lawson [LAWS 98] conducted an experiment that clearly shows that the addition of sound increased the reported level of engagement as defined by focussed attention. After further evaluation of Lawson's data, it can be concluded that the inclusion of sound also increases the reported level of presence (Figure 7). However, there does exist some ambiguity with this statement.

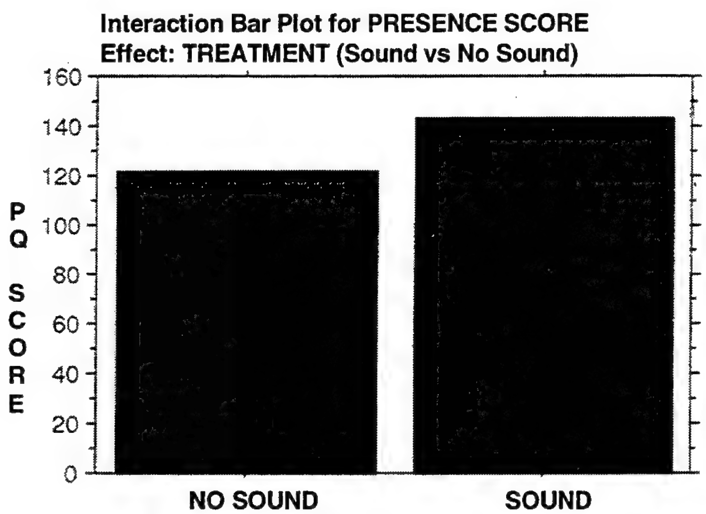


Figure 7: Comparison of Sound Treatments as a Function of PQ Score

The experiment in question used non-spatialized sound that included verbal information that was both semantic (topical) and spatial. The semantic component of sound included the sound of the vehicle's engine and the radio as well as information provided via an automated recording. The spatial component was contained in the automated recording to include absolute as well as relative locations of landmarks within the VE. These sound components clearly increased the level of presence, which can be seen in Figure 7. However, it is unclear whether

both of these components were required to produce the feeling of presence or if only one of the components was required.

Thus, the following concept was developed for this experiment. What effect does non-spatial, semantic sound have on presence as compared to sound that only includes spatial information? In addition, does including both the semantic sound and spatial sound components produce greater levels of presence? In other words, is the sum of the sound components greater than the individual parts as measured by presence?

B. RELATING PRESENCE AND PERFORMANCE

In reviewing the work of Lawson, the level of engagement increased when non-spatialized sound cues were introduced. When given a post-VE quiz, participants who received the sound treatment scored higher than those who did not receive sound cues. This quiz did not measure the ability to acquire spatial knowledge, since it was not the focus of his research, however the quiz did include questions that were spatial in nature. Examples of these questions include, but were not limited to, "What was directly across from the library?" and "Where did your trip begin?" However, few conclusions can be drawn from this data regarding the effect of presence on spatial awareness since it was not fully investigated. But since presence has been shown to correlate with the level of engagement [LAWS 98] and engagement resulted in participants being better able to answer questions that in some cases were spatial in nature, it is reasonable to assume that presence must play some role in participant's spatial awareness. Based on this assumption, the experiment for this thesis was designed to measure performance of a spatial task. This will provide a means to determine if the level of presence is a predictor of performance of spatial tasks in VEs.

C. RELATING SOUND AND PERFORMANCE

The previous ideas imply a further relationship. If improved performance can be correlated with increasing levels of presence, and presence was increased due to the inclusion of sound cues, then it follows that increasing sound should lead to an increase in spatial comprehension. Although this argument makes sense on the surface, it is illogical to conclude that sound, in and of itself, would affect a person's ability to acquire spatial knowledge, particularly when the sound is not spatialized.

Three dimensional (3D) spatialized sound in VEs can be described as sound that provides the listener with a sense of the location of a virtual sound source. For example, a 3D spatialized sound of an airplane will provide a sense that the sound is coming from overhead and will appear to the user to come from a particular location in the space outside the listener's head. Spatialized sound has been found to increase the level of presence in VEs when compared to non-spatialized sound or no sound environment [HEND 96]. While this is valuable research, the relationship between presence and non-spatialized verbal cues was not examined in this experiment. Does the use of non-spatialized sound that includes spatial content increase presence? Also, what if the verbal cues only provide semantic information? Non-spatialized sound, regardless of whether or not it contains spatial content, is likely to be able to direct the user's attention to particular objects in a VE. If you are told that there is an airplane directly overhead, or if you hear that plane overhead, both should result in the user looking up.

As asked earlier, does the type of non-spatialized sound in the VE impact presence and thereby impact the ability to acquire spatial knowledge? To answer this question we need to identify components of sound and to determine their impact on presence and performance. For

this experiment it was determined that two major components of non-spatialized sound would be examined. The components were the semantic and spatial sound components.

The semantic sound component can be described as those sounds that do not provide any spatial information or simple ambient noise. For this experiment, the sound of the vehicle's engine and radio are considered ambient noise, while the verbal cues that provide topical information are considered to be the non-spatialized semantic sound component. Providing a participant with information about the age of a building, but not its location would be an example. A non-spatialized spatial sound component would be the absence of ambient noise and the inclusion of verbal cues that are specifically designed to provide the participant with spatial knowledge. An example would include providing the participant with information that a particular landmark is located on the northeast corner of the town.

D. EXPECTED RESULTS

The hypotheses of this thesis lead to the following prediction. Participants who experience high levels of presence will acquire more spatial knowledge than those who experience lower levels. Further, those who receive any sound cues will report experiencing higher levels of presence than those who receive no sound cues. However, among the sound treatments, those who receive semantic or topical sound information will report higher levels of presence than those who receive verbal cues containing only spatial content, while those who receive spatial information will perform better on all spatial tasks. Lastly, those who have a high level of innate spatial abilities will out perform those who do not, but among those of equal ability, the level of presence should be a determining factor of performance.

This page intentionally left blank.

IV. METHOD

A. EXPERIMENTAL DESIGN

The experiment was a between group design with the sound condition being the independent variable. The sound treatments were (1) No Sound, (2) Verbal Cues with Semantic and Topical Information Only, (3) Verbal Cues with Spatial Information Only, and (4) Spatial and Semantic Information Combined. The semantic group received information that contained no spatial information such as "The Catholic church is the oldest building in Marsville" and contained non-spatialized sound that simulated the vehicle's engine and radio. The spatial only group received information that only described spatial aspects of the VE. For instance, "The church on your left is located on the northeast corner of town, one block from the library." Accordingly, the combined semantic and spatial group received a combination of the two treatments mentioned previously.

The dependent variables included responses to questionnaires and a number of spatial knowledge measures. The two questionnaires used were the Presence Questionnaire (PQ) and the Immersive Tendency Questionnaire (ITQ). The ITQ measured the participant's immersive tendencies to become involved prior to the VE treatment. The PQ was used to measure the subject's sense of presence within the VE [WITM 98]. These questionnaires were used to determine the level of presence experienced by each subject. The questionnaires are self-assessments and therefore subjective by nature.

The spatial knowledge measures were developed to be both egocentric and exocentric in nature. The egocentric measure is a pointing task. A map building exercise was used as the exocentric task. These tasks will be described in detail later in this chapter.

B. HYPOTHESIS

The hypotheses for the experiment are as follows:

- The level of presence in a VE will increase the amount of spatial knowledge acquired in a virtual environment.
- Given four different auditory treatments, individuals will experience a higher level of presence in a virtual environment given any sound cues compared to those who receive no sound cues.

The sub-hypotheses for the experiment are as follows:

- Those participants who receive verbal cues with spatial content will score higher on all spatial tasks as compared to those who receive no sound cues or only semantic sound cues.
- Those participants who score higher on the Building Memory Test will score higher on the Map Building Test (procedural and route knowledge).
- Those participants who score higher on the Guilford-Zimmerman Test will score higher on the Pointing Task Test (survey knowledge).
- Those participants who score higher on the Magnet Board Test will score higher on the Pointing Task Test.

C. PARTICIPANTS

Forty participants (33 male and 7 female with an average age of 32.5) participated in the experiment. Each treatment was administered to ten subjects. Prior experience with VEs varied among all subjects and within each group. Subjects were assigned to groups at random. The only

reason participants were disqualified was that they had been in the VE prior to being tested. All participants had normal or corrected to normal vision and all spoke English fluently.

D. BASIC TASKS AND APARATUS

The main task in the experiment involved going through a virtual environment from the perspective of an automobile passenger and remembering the buildings, the locations of those buildings, and the route traveled through the virtual town. All participants were briefed on how these tasks were going to be measured as well as being able to see how the tests were going to be conducted. All groups were given identical instructions throughout the experiment.

All participants were given the same visual display, three large televisions that displayed a 133-degree field of view of the VE (Figure 8). All sound stimuli were generated from speakers placed behind the participant.

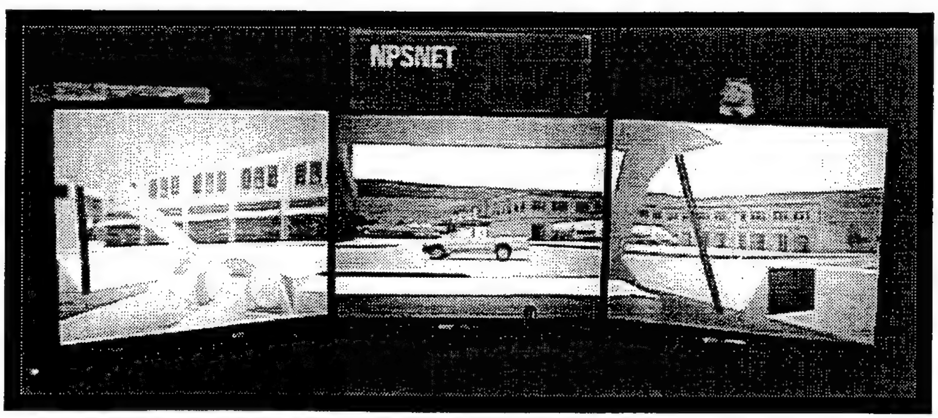


Figure 8: Three-Screen Display

E. MEASURES

Measuring presence in VEs has been studied a great deal in the past few years. Currently, there is not an objective means of measuring this phenomenon. However, there is a great deal of data to suggest that the self-assessed Presence Questionnaire (PQ) developed by Witmer and Singer [WITM 98] does provide a valid way to measure presence, but it is subjective and its repeatability is questionable. The PQ measures the degree to which individuals experience presence in a VE, but also suggests what contributing factors affected the intensity of the experience. This questionnaire was used for this study in order to correlate spatial comprehension with presence.

Measuring spatial knowledge has also been studied in great detail, however it was important that all three types of spatial knowledge, landmark identification, route and procedural, and survey knowledge, be captured in the results. To measure the amount of survey knowledge acquired, a Pointing Task Test was used. It was conducted at the conclusion of the trial in the VE. A short sequence (approx. ten seconds) was replayed bringing the subject to a specific, predetermined location in the VE via the same route traveled in the trial. At this location the subject was asked to point to a number of locations which are outside the current view or at least occluded in the current view. This was done using a circular protractor mounted to the desk in order to acquire as precise a measurement as possible (Figure 9).

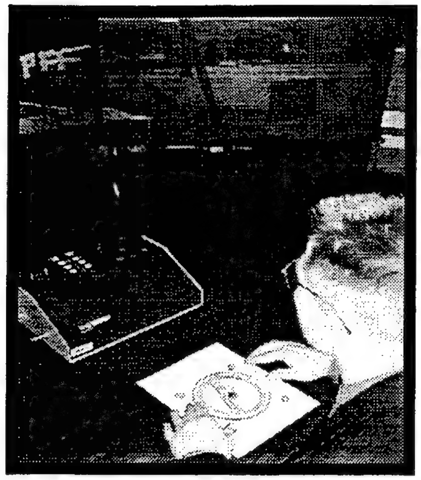


Figure 9: The Egocentric Pointing Task with Protractor Device Mounted to Table

To determine the amount of landmark and procedural knowledge acquired in the VE, a Magnet Board Test was used (Figure 10). This second measurement of spatial comprehension is a Map Building Task. It was conducted at the conclusion of the VE trial and after the Pointing Task. Each subject is brought to a table and given a set of magnetic representations of buildings and landmarks that may or may not have been seen during the trial. The task begins by having each subject selecting all the magnets that can be remembered among all the choices presented. At this point, a metal board on which a road network of the VE is depicted is provided to the subject. The subject is then instructed to place the magnets selected on the map. Finally, using a set of magnetic strips, the subject is asked to describe the route taken through the town. The entry and exit points are given as well as the objects used during the Pointing Task Test, however the orientation of the map is left to the subject. It should be noted that the placement of the magnets and the identification of the route were done simultaneously with each subject completing the tasks in the order of their choice. A number of spatial measures are computed from these tasks. The landmark identification score is the number of correct landmarks that were

selected from the original set of magnets. The map building score is an aggregate score computed by the placement of the landmark magnets on the route network and the identification of the route.

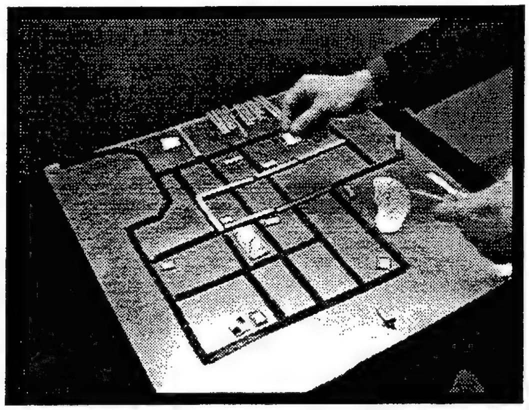


Figure 10: The Exocentric Map Building Task Using Magnets

The map building task was used to overcome inherent deficiencies with map drawing tasks that have been used in the past. Although it is a visually dominant task, it has the advantages of a free-recall task [FRAN 71][ROEN 78]. By allowing the subject to develop the environment over time rather than in a sequential fashion, which is required in a map drawing exercise, the subject is more able to precisely complete the task (Figure 11). This measurement was developed from a simple target placement task used in a previous experiment [GEOR 98].

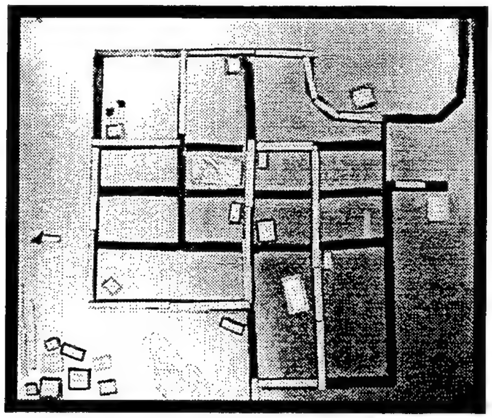


Figure 11: Completed Map Building Task

F. CONTENT

The VE storyline involved each subject being a passenger in an automated vehicle. This vehicle was owned by a local realty company and was going to take each subject on a tour of the town. Each subject was given audio stimuli that provided information regarding the town with the exception of the No Sound Treatment.

The tour began just outside of the town and ended shortly after leaving the town. While in town, subjects were given information about various landmarks both visual and auditory in nature. The content of the auditory portion varied by treatment. In the semantic only treatment, subjects were provided information that contained no spatial references. It was limited to describing other aspects of the town, such as the age of a building. Additionally, other sounds were included. They were the sound of the vehicle's engine, other vehicles in the town, and the vehicle's radio. The spatial only treatment was limited to including only spatial references, such as a building being located on the Northwest corner of town. All other sound was removed. The spatial and semantic combined treatment included both the semantic and spatial treatments to

provide not only spatial references but non-spatial information as well. Finally, the no sound treatment occluded all sound.

The only interaction with the VE provided to each subject was via the joystick, which gave the ability to move the subject's head, but did not control the vehicle's movement in any way (Figure 12). The vehicle's route and speed were under the control of the computer and provided consistent information across all treatment groups.

Figure 12: BG Systems Flybox

G. PROCEDURES

Step One: The experimental area was completely set up prior to the arrival of each subject (See Appendix B). The participant was given a detailed in-brief (See Appendix C) outside the experimental area. Each subject was asked to read and sign the Consent and Privacy Act Forms (See Appendix D). The subject was then asked to complete a set of pre-

questionnaires and spatial ability tests (See Appendix E). Once all the pre-questionnaires and tests were completed they were escorted to the experimental area to proceed with the experiment.

Step Two: Once each subject entered the experimental area they were instructed to be seated in front of the three-screen display. They were then given a brief on the tasks to be completed. This included physically showing them the Pointing Task Test and Magnet Board Test apparatus (See Appendix C). The purpose of doing this was to ensure every subject understood what to pay attention to during the experiment. Before starting the experiment each subject was familiarized with the Flybox and its capabilities. After each subject demonstrated that they understood how to utilize the Flybox, the experiment began.

Step Three: When the first VE experience ended, the subject was administered the Pointing Task Test (See appendix E) and the Magnet Board Test (See Appendix E). Next, each subject was given the Presence Questionnaire (See Appendix E). This concluded the first exposure.

Step Four: All participants were then given the opportunity to take a five-minute break. At the conclusion of the break, each subject was given the identical VE experience received during the first experience. When the second VE experience ended, the subject was again administered the Pointing Task Test followed by the Magnet Board Test. The participants were not able to view their responses to the first test with one exception. On the second Map Building Task, the subjects were given the original route from the first Map Building Test. All other aspects of the test remained the same. At the conclusion each participant was given a short debriefing and allowed to ask questions. This concluded the experiment.

This page intentionally left blank.

V. ANALYSIS

A. INTRODUCTION

This chapter reports the results of the experiment that investigated the amount of spatial knowledge acquired in a VE as a function of presence. The dependent measures for every treatment included the Presence Questionnaire (PQ), Landmark Identification Score, Map Building Score, and Pointing Task Score.

The PQ was used to measure the subjects' self-assessed level of presence in the VE. The score was computed by summing the subjects' responses to the questions that were on an eight-point scale.

The Landmark Identification, Map Building, and Pointing Task scores were used to measure the amount of spatial knowledge acquired in the VE. The Landmark Identification score was computed by giving each correctly identified landmark one point. There were no penalties for incorrect landmark identification. The Map Building score was computed by rating each of the landmarks selected on a scale of four. Each landmark placed on the map was given one point for its selection, one point for its location based on absolute location, one point for its location relative to the route taken, and one point for its location relative to other objects. The Pointing Task score was computed in two ways. First, Pointing Task scores were computed by giving one point for every task that was within fifteen degrees of the correct answer and no points for answers that exceeded fifteen degrees. Additionally, the average deviation on all pointing task measures was computed.

B. POWER ANALYSIS

Unless otherwise noted, the tests reported here are simple regression analyses between four different treatments: no sound, verbal cues without spatial content and background noise, verbal cues with spatial content only, and a combination of verbal cues with and without spatial content and background noise. The sample size was forty participants. An alpha value of 0.10 was used, resulting in a power value (1-Beta) of 0.6334. Therefore, the ability to reject the null hypothesis may be unreliable. This suggests that drawing conclusions based on the inability to identify a positive effect on any factor may be inconclusive.

C. PRIMARY RESULTS

1. Primary Hypothesis:

As the level of presence in a VE increases the amount of spatial knowledge acquired in a virtual environment will also increase.

Determining the effect presence has on the ability to acquire spatial knowledge requires that each aspect of spatial knowledge be examined. Landmark, procedural and route, and survey knowledge were analyzed to determine if there exists a correlation with presence. This section examines each type of spatial knowledge individually to understand how each is affected by presence.

Measuring the differences among all the spatial knowledge tests, we can make a comparison between the level of presence and the amount of spatial knowledge acquired, irregardless of the treatment received, as measured by the Map Building and the Pointing Task Tests. A simple regression test was used with the Presence Questionnaire score as the independent variable and the spatial task scores as the dependent variables.

The first type of spatial knowledge to be examined is landmark identification. Landmark identification was measured by participants identifying landmarks they had seen in the VE from a group of possible landmarks that were symbolically represented by magnets. The results, F(1,39) = 2.043, P = 0.1609, suggest that the ability to identify landmarks was not significantly different as a function of presence (Figure 13). This implies that presence does not impact the ability to acquire landmark knowledge.

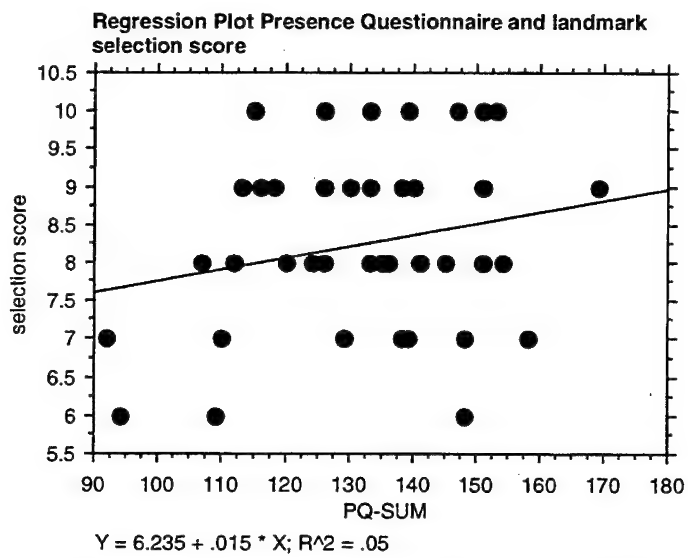


Figure 13: Regression Analysis of Presence Questionnaire and Landmark Identification Task

These results were not unexpected. Satalitch [SATA 98] found that the ability to identify landmarks was unaffected regardless of whether the information was presented via video or from the real world. This research and the data suggest that presence is not required to enhance, nor does it enhance, a person's ability to identify landmarks. For example, many people have not visited New York City. However, most are capable of identifying the Empire State Building and Statue of Liberty. This implies that landmark identification is in large part a visual memory exercise that does not require one to feel present in an environment, real or virtual, to acquire

knowledge that is purely visual. Additionally, since the landmarks were represented symbolically instead of actual landmark images, participants were required to build a mental picture of the landmark then recall if that landmark had been seen in the VE. For instance, for a participant to select the Catholic Church, a mental picture of the church (as seen in the VE) must be built in order for it to be selected. This resulted in few participants selecting landmarks that were not represented since they did not have a mental picture to assign to the landmark. Therefore, the variances of the results were due to the non-selection of landmarks that were present in the VE, not the incorrect selection of landmarks not represented. This implies that a person's visual memory was more responsible for the results than the level of presence experienced by the participant.

The second type of spatial knowledge examined is route and procedural knowledge that was measured via the Map Building Test. Participants were given a road network of the VE town and asked to correctly place landmarks on the map as well as identify the route taken through the VE. The Map Building Task was not impacted by the level of presence, $F(1,39) = 0.466$, $\underline{P} = 0.4989$ (Figure 14). This suggests that the ability to acquire procedural and route knowledge is not significantly affected by differing levels of presence. Figure 14 shows that as the level of presence increased there was not a corresponding increase in the Map Building Score. For example, the participant with the highest reported level of presence (170) was less than fifty percent successful in completing the Map Building Task.

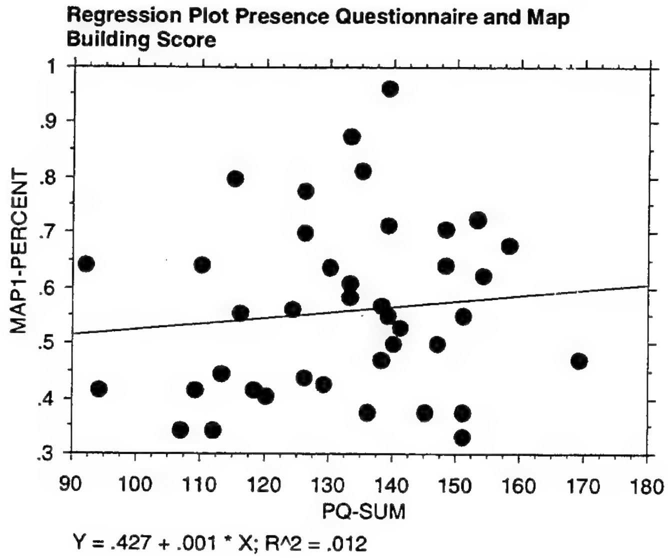


Figure 14: Regression Analysis of Presence Questionnaire and Map Building Score

The result that presence was generally not a factor in contributing to the acquisition of landmark and procedural knowledge can be attributed to the fact that they are both visual memory exercises. A participant who experienced a higher level of presence did not improve his ability to acquire route and procedural knowledge from the VE. The visual memory aspect of the task appears to have been the determining factor in acquiring both landmark and procedural knowledge. This supports the work of Thorndyke [THOR 80] who found that route knowledge could be acquired by direct exposure or through simulated experiences such as video. This suggests presence is not necessary for acquiring landmark or procedural knowledge, and in this study did not enhance, nor degrade, the ability to acquire route and procedural knowledge.

The last type of spatial knowledge to be examined is survey knowledge. Survey knowledge was measured via a Pointing Task. Participants were asked to point in the direction of various landmarks in the VE that were either occluded or outside the participant's field of view.

When looking at a comparison between presence and the ability to acquire survey knowledge in a VE, the results show that the level of presence has no effect on the ability to

acquire spatial knowledge. The results, F(1,39) = 0.044, P = 0.8359, show that the degree to which there is no significant difference is substantial (Figure 15).

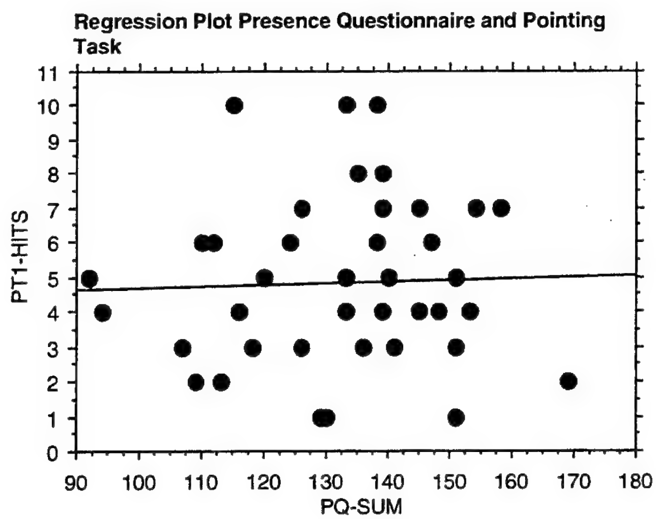


Figure 15: Regression Analysis of Presence Questionnaire and Pointing Task Hits

This indicates that the ability to acquire survey knowledge is not only independent of the level of presence, but rather heavily dependent on the subject's innate spatial abilities. Further, based on the earlier results and the idea that survey knowledge is enhanced by knowledge learned at lower levels (landmark and procedural knowledge), as Thorndyke [THOR 80] suggests, presence was not a determining factor in the amount of survey knowledge acquired. However, the amount of procedural and landmark knowledge did affect the amount of survey knowledge acquired, suggesting that the visual memory aspect of the Map Building Task and the theory that spatial knowledge is gained hierarchically (Figure 1) as Thorndyke's model shows, were major contributing factors. The results, F(1,39) = 0.044, P = 0.0021, show conclusively that as the Map Building Task Score improves the number of "hits" recorded during the Pointing Task is also likely to improve (Figure 16).

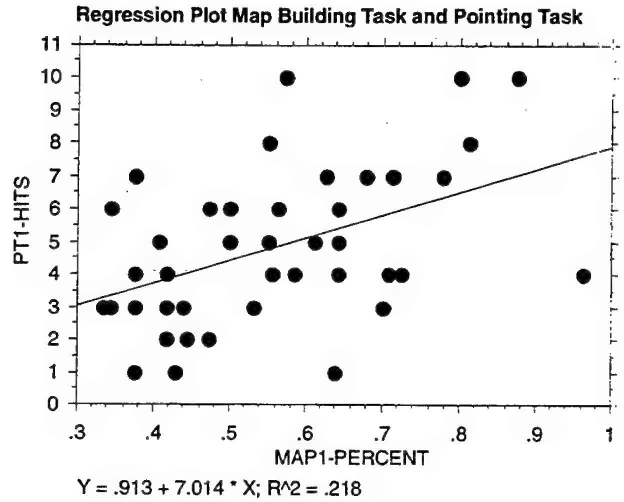


Figure 16: Regression Analysis of Presence Questionnaire and Pointing Task Hits

2. Secondary Hypothesis:

Given four different auditory treatments, individuals will experience a higher level of presence in a virtual environment given any sound cues compared to those who receive no sound cues.

An objective comparison can be made between the four treatments with regards to the reported levels of presence. An ANOVA Post-hoc Test was used with the PQ score as the dependent variable. Figure 17 shows that the introduction of sound of any type significantly increases the reported level of presence experienced in a VE with a reported $F(3,37) = 3.897$, $\underline{P} = 0.0162$. In all cases, the introduction of sound increased presence when compared to the No Sound treatment, however there were no significant differences between any of the Sound treatments. The results in this case are conclusive. The interesting point is that there is a significant difference between any treatment that introduces sound cues as compared to the No Sound treatment. This is in accordance with the findings from Lawson [LAWS 98]. This also

supports the past results as reported by Gilkey [GILK 95] and Hendrix [HEND 96] that suggest aural stimuli are a necessary factor in increasing the level of presence in a VE.

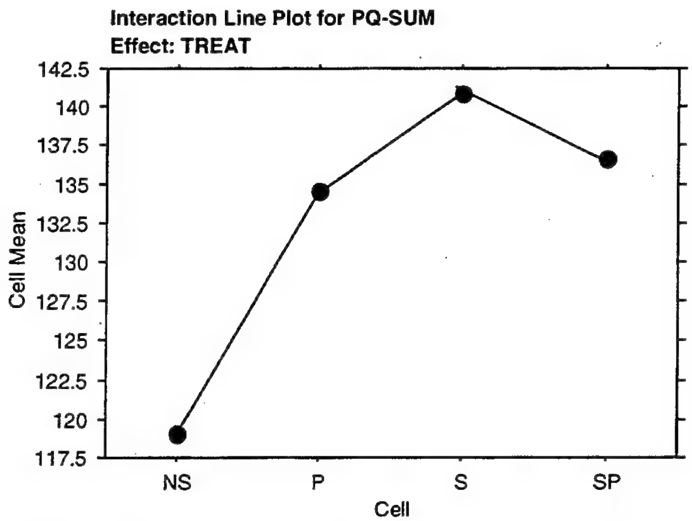


Figure 17: Presence as a Function of Sound Treatments

However, comparing the various sound treatments, the treatment that provided only verbal cues with spatial content provided the highest level of presence. Based on the theory that presence is the feeling of being in another place, the other treatments that included sound such as the vehicle engine and radio should provide a higher sense of presence. Why is this not the case? It appears that these other sounds acted as a distracter from the primary task to acquire spatial knowledge, particularly when compared to the verbal cues with spatial content and background noise since this treatment contained the same spatial content that was provided by the spatial only treatment. Further evidence of this is the fact the treatment that contained verbal cues without spatial content also produced lower levels of presence. Although in this case the verbal cues provided information related to the landmarks, they did not provide any information with regards to the primary task (acquiring spatial knowledge). Although the results were inconclusive, they suggest

that presence increases with the inclusion of sound, but if the sound is unrelated to the primary task the resulting level of presence may be lower.

If the data is examined and the questions that are directly related to sound are removed, the results change. An example of these questions would be "How did the auditory aspects of the environment involve you?" and "How well could you identify sounds?" One might think that these questions were the reason for the primary results, which clearly indicate that presence was enhanced with the inclusion of sound. Figure 18 shows that after the sound specific questions are removed from the PQ score, the results only change slightly.

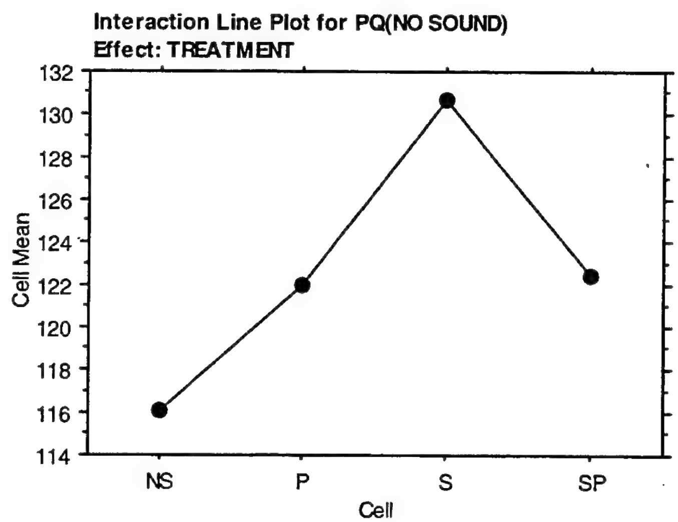


Figure 18: Presence as Function of Sound Treatments (without PQ sound questions)

The treatment that provided only verbal cues with spatial content was again significantly different from the No Sound treatment. While any comparisons between the remaining treatments are inconclusive, this data does continue to suggest that the inclusion of non-spatialized sound increases presence and the inclusion of non-spatialized sound that can be described as "task related" produce higher levels of presence than those treatments that are not task related.

Further scrutiny of the PQ reveals the reason for the increase in the level of presence for the treatment that included only verbal cues containing spatial content. Since the primary task was the acquisition of spatial knowledge, those PQ questions that relate to spatial awareness or were task specific in nature were examined. These questions included PQ question numbers 10, 12, 14, 18, 19, 20, 21, 27, 30, 31, 32 (See Appendix E-4). Figure 19 and Table 1 show that the spatial only treatment was significantly better than the other sound treatments. This suggests that exclusively including sound that is relevant to the primary task improves the level of presence in a VE.

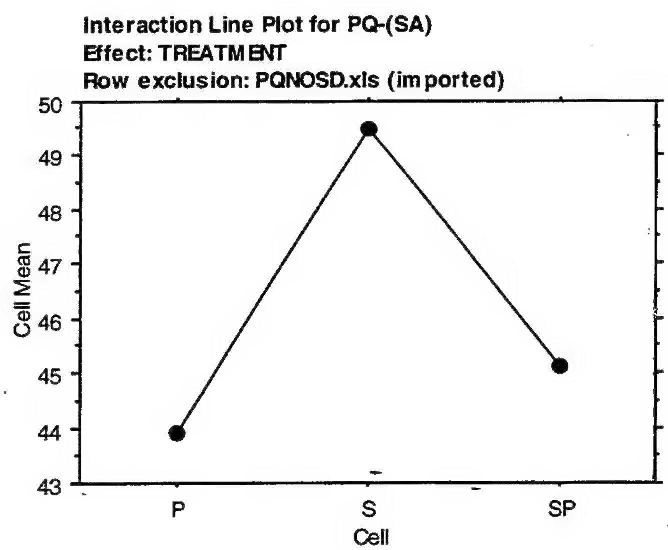


Figure 19: Presence as Function of Sound Treatments (only PQ Spatial Questions)

Fisher's PLSD for PQ-(SA)
Effect: TREATMENT
Significance Level: 5 %
Row exclusion: PQNOSD.xls (imported)

	Mean Diff.	Crit. Diff	P-Value	
P, S	-5.600	5.518	.0469	S
P, SP	-1.200	5.518	.6590	
S, SP	4.400	5.518	.1134	

Table 1: Presence as Function of Sound Treatments (only PQ Spatial Questions)

Based on the theory that attention is positively correlated with presence via increased immersion [LAWS 98], it is reasoned that verbal cues without spatial content caused participants to focus on disregarding this information taking their attention away from the primary task. This superfluous information caused participants to split their attentional resources, which resulted in lower levels of presence. Further, combining spatial content with non-spatial content again required participants to filter out the superfluous information, thus splitting their attentional resources. This "split" of attention again resulted in lower levels of presence, even though all the relevant spatial information was still provided.

These results suggest that the rush by developers to include all sounds and stimuli that are found in the real world may be unnecessary. The goal of VE in most cases is to enhance learning and enjoyment, so while some superfluous sounds may provide realistic audio stimuli, their inclusion does not necessarily translate to better VE design and performance or higher levels of presence. The results suggest that varying a component of immersion (sound) impacts multiple components of presence (spatial awareness and attention) and these effects may counteract one another with the overall result of lower presence.

3. Sub-Hypothesis:

First Sub Hypothesis: ***Those participants who score higher on the Building Memory Test will score higher on the Map Building Test (procedural and route knowledge).***

A comparison of the Building Memory Test score and the Map Building Test Score can be made. Using a simple regression with the Building Memory Test as the independent variable and the Map Building Score as the dependent variable, there was conclusive evidence that a high score on the Building Memory Test lead to an improved score on the Map Building Task (Figure 20).

Results, $F(1,39) = 6.554$, $\underline{P} = 0.0039$, suggest that a participant's innate ability as measured by the Building Memory Test are predictive of performance on the Map Building Test.

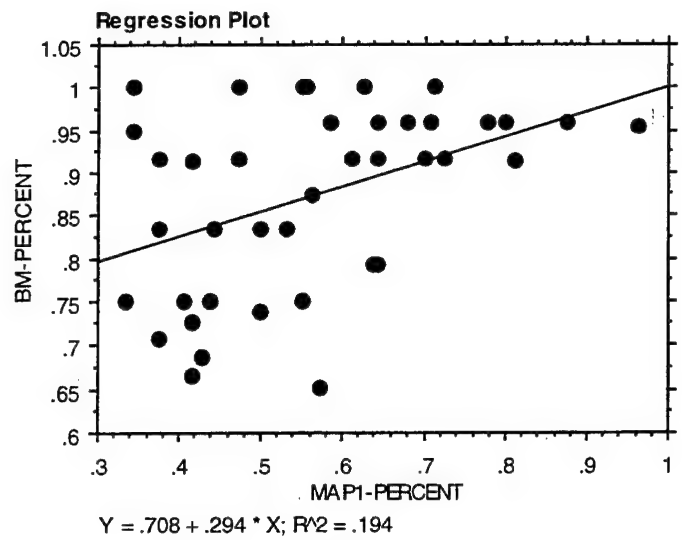


Figure 20: Regression Analysis of Building Memory Test and Map Building Score

These results are due to the fact that both are strictly visual in nature and both are done from an exocentric point of reference. The Map Building Test and the Building Memory Test are both a purely visual memory exercises. However, when sound is introduced, the means of providing information is bimodal instead of strictly limited to the visual modality. Since this information is largely unrelated to acquiring spatial knowledge it does not significantly affect the Map Building Score. Therefore, the Building Memory Test is predictive of the Map Building Score even though the means of acquiring spatial knowledge is no longer limited to the visual modality, but includes aural stimuli, which is not taken into account by the Building Memory Test.

A comparison of the Building Memory Test score and the score on the spatial knowledge acquisition tests relating to survey knowledge can be made. The results, $F(1,9) = 6.118$, $\underline{P} = 0.1633$, suggest that there are no significant differences among Building Memory scores and the

Pointing Task Tests (Figure 21). This implies that while the Building Memory Test is a visual memory test, the Pointing Task Tests, which require survey knowledge, are not. Although these results are not conclusive, it does support [SATA 95].

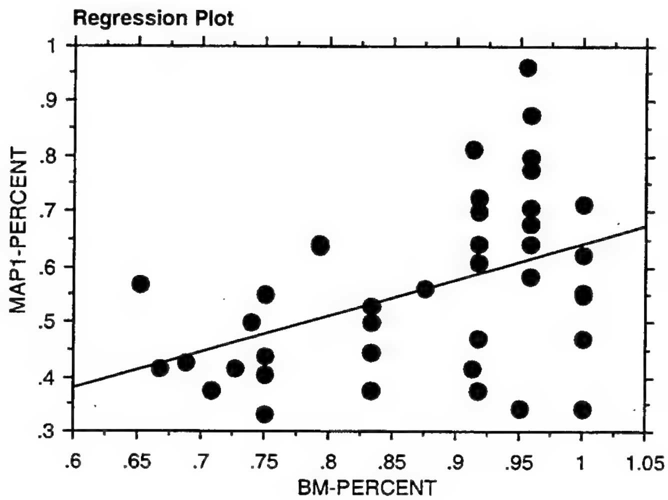


Figure 21: Regression Analysis of Building Memory and Pointing Task Hits

Second Sub Hypothesis: ***Those participants who score higher on the Guilford-Zimmerman Test will score higher on the Pointing Task Test (survey knowledge).***

The study also provided a comparison between the results of the Guilford-Zimmerman Spatial Aptitude Test and the Pointing Task Test. A simple regression test with the Guilford-Zimmerman score as the independent variable and the Pointing Task score as the dependent variable was conducted. The data suggests that the score on the pointing tasks improved as a function of the Guilford-Zimmerman Spatial score. The results, $F(1,39) = 2.817$, $\underline{P} = 0.1012$, indicate that there is a difference between the average degree of error and the Guilford-Zimmerman score. Further analysis reveals that the Guilford Zimmerman becomes predictive of the Pointing Test Task when spatial references are included. Figure 22 shows the relationship of the Guilford-Zimmerman Test score and the Pointing Task score for all treatments.

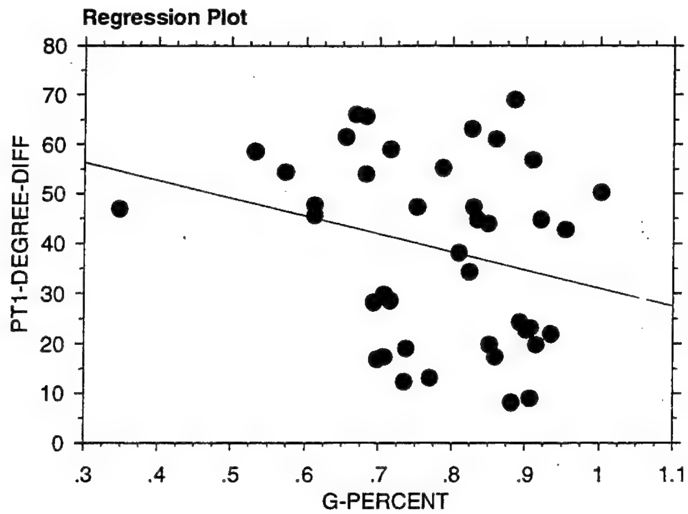


Figure 22: Regression Analysis of Pointing Task and Guildford-Zimmerman Test

The Pointing Task Test is a measure of the amount of survey knowledge acquired. Since survey knowledge is thought to be the most difficult to acquire, it follows that a participant with higher spatial abilities would have a better Pointing Task Score. This result implies that innate spatial abilities are more important than presence in gaining survey knowledge in a VE.

It is interesting to note that after the second VE experience, scores on the pointing task, $F(1,39) = 1.209$, $\underline{P} = 0.2816$, did improve, but there was not a significant difference between the second Pointing Task Score and the results of the Guilford-Zimmerman Test. This result was unexpected since the second exposure would allow for the acquisition of more survey knowledge. However, the improved scores were not strongly related to the innate abilities of the subjects.

Third Sub Hypothesis: ***Those participants who score higher on Map Building Test will score higher on the Pointing Task Test.***

Comparing the results of the Map Building Test and the Pointing Test there was a significant difference, $F(1,39) = 12.13$, $P = 0.0021$, which indicates that a high score on the Map Building Test will lead to a high score on the Pointing Task Test. This supports the claim that

survey knowledge is improved with better procedural knowledge [GOER 98]. Figure 23 suggests that the Map Building score is predictive of the amount of survey knowledge acquired.

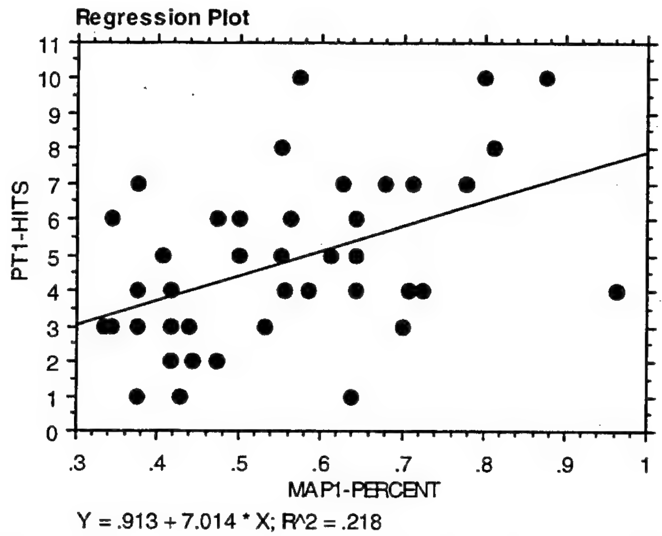


Figure 23: Regression Analysis of Map Building Score and Pointing Task Score

A high Map Building score indicates that a high level of procedural knowledge was acquired. This procedural knowledge enhanced the user's ability to acquire survey knowledge. As Thorndyke's Hierarchical Model suggests, knowledge at one level (survey) is enhanced by knowledge gained from the previous level (procedural).

D. SUMMARY

The results of the various comparisons made throughout this chapter suggest the following. First, including non-spatialized sound in a VE display does increase the level of presence, however if the sound is exclusively related to the primary task the level of presence is further increased. Second, presence is not a predictor of performance of spatial tasks in a VE. The data suggests that other factors are more predictive of spatial performance. Individual spatial abilities and visual memory are better predictive measures of spatial performance as compared to presence. Last, the

associative relationship discussed in chapter III between non-spatialized sound, presence, and spatial performance does not exist.

The initial thought was that the addition of non-spatialized sound would increase performance of spatial tasks. This was based on three main ideas. First, including verbal cues with only spatial content was thought to increase performance based on the idea that using multiple modalities to convey spatial information would result in improved performance. Second, including verbal cues without spatial content would improve performance simply based on hypothetical models of working memory [BADD 78]. Last, including both spatial and non-spatial cues would improve performance based on the combined effects of the previous two ideas. However, the results show that this is not the case. Results indicate that including topical information such as that which was contained in the verbal cues without spatial content does not provide any help with indexing memory as had been anticipated. Although including verbal cues with spatial content appears to improve performance, the results were inconclusive and contradictory in some cases.

Figures 24, 25, and 26 show the results of an ANOVA post-hoc test conducted on the three measures of spatial performance. There were no significant differences among the treatments, but the data and figures below suggest performance of all spatial tasks is improved with the exclusive inclusion of verbal cues with spatial content, while those who received verbal cues without spatial content generally performed poorly as compared to the other treatments.

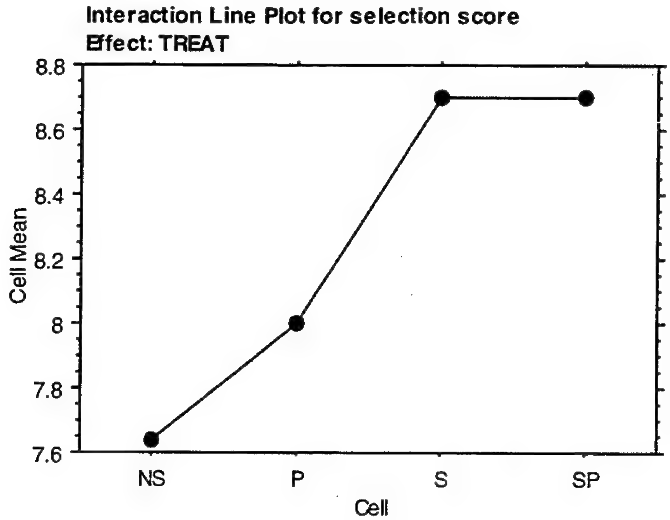


Figure 24: Treatments vs. Landmark Selection Score

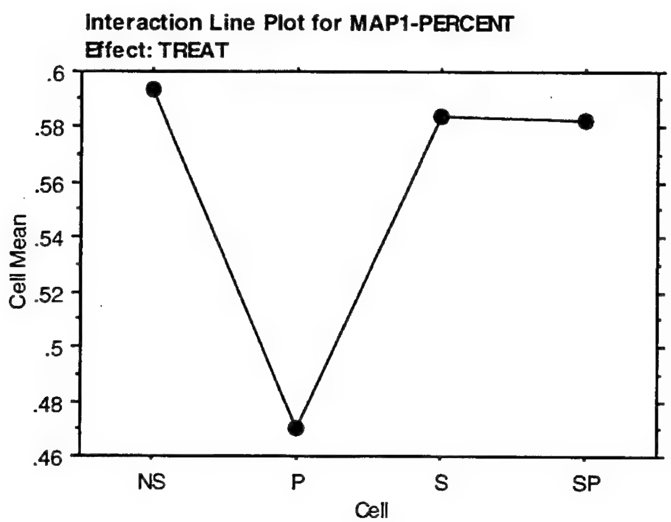


Figure 25: Treatments vs. Map Building Test

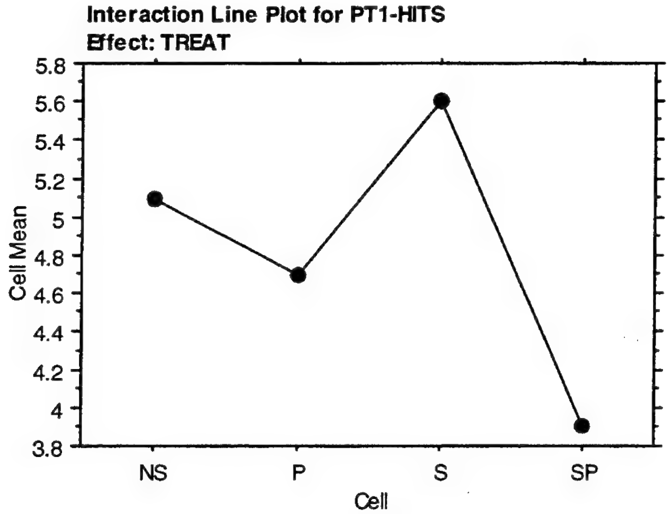


Figure 26: Treatments vs. Landmark Selection Score

Additionally, the no sound group performed better on the Map Building Task and performed much worse on the Landmark Selection Task as compare to the other treatments. Those who received the combined treatment of verbal cues containing both spatial and topical information performed as well as the spatial group on the Landmark Selection and Map Building Task, but performed more poorly than all other groups on the Pointing Tasks. Therefore, the results do not generally support the use of non-spatialized sound as a measure of spatial performance. However, based on the counterintuitive nature of these results it should be clear that more research is needed in this area.

VI. CONCLUSIONS

A. SUMMARY

The purpose of this study was to investigate the effect that presence has on the ability to acquire spatial knowledge in a VE. Additionally, the effect of including various non-spatialized sound cues on the level of presence in a VE was examined.

The experimental design was based on the idea that if presence could be shown to improve performance on spatial tasks and that non-spatialized sound could increase the level of presence, then sound could be correlated with the ability to perform spatial tasks. The results were inconclusive, however it cannot be assumed that presence does not impact performance in some manner. Presence may not affect performance in general, however it may later be shown that presence may, in fact, affect specific types of performance on specific tasks. However, this will require further research. Additionally, the results do suggest that there are elements of presence that are not related exclusively to non-spatialized sound, but relating these sounds to performance was inconclusive.

In summary, the significant findings of this study are as follows:

- Results indicate that the level of presence had no significant effect on the ability to acquire spatial knowledge in a VE.
- Including non-spatialized sound cues in the display significantly increased the reported level of presence in a VE.
- The types of non-spatialized sound, whether or not they contain spatial content, contribute to higher levels of presence.
- As the amount of procedural and route knowledge increases, the amount of survey knowledge also increases.

These results provide important information on the importance of presence in VEs. Although this study suggests that presence was not required for acquiring spatial knowledge, there is likely other knowledge and learning that can be enhanced if the VE provides a greater sense of presence to its users.

B. RECOMMENDATIONS

In reviewing the data there are several ways in which the experiment could have been improved. First, the sound treatments should have been further decomposed into specific components. Every sound treatment contained verbal information that was either spatial or non-spatial in nature. In retrospect, the experiment should have contained a treatment that had no verbal information, but rather only that of the vehicle's engine and radio. This would have provided more evidence that <u>any</u> sound increases the reported level of presence. It should be noted that this was done during an early pilot study and the results, although anecdotal in nature, suggested that presence increased with only the car's engine and radio.

Second, it is recommended that the Landmark Selection Task and Map Building Test be converted from exocentric tasks to egocentric tasks. The methods used required participants to complete a 90-degree mental rotation of the VE in order to complete the tasks even though all knowledge was acquired from an egocentric viewpoint. For example, the Building Memory Test required participants to transform all knowledge of the landmarks and route gained from the egocentric point of view to an exocentric point of view that was required of the Map Building Task. This could be done by administering an egocentric Landmark Selection Task and Map Building Test. Having each participant manually navigate the VE and identify landmarks within the VE would accomplish this. The landmarks could be represented as gray boxes and the

participant would simply identify what landmark was located in that position during the initial VE experience. The benefit would be that participants who are poor at mental rotations would no longer have to make the rotations and the shortcomings of the symbolically represented landmarks would be eliminated. Additionally, the Pointing Task could be conducted simultaneously thus reducing any learning that may occur as a result of administering the Pointing Task prior to the Landmark Selection Task and Map Building Test.

Last, it would be interesting to know how presence affected a subject's ability to recall the spatial and topical knowledge at a later time. The experiment was conducted with both treatments being administered in a short period of time. This leaves the following question unanswered: Are subjects who experience higher levels of presence better able to recall spatial and topical information over time than those who experience lower levels of presence? Perhaps an experiment that tested subjects a week after their initial exposure would answer this question. Including these elements would provide more insight into the effects of presence as well as valuable knowledge for future research.

C. FUTURE WORK

This thesis has explored the relationship between presence and the ability to acquire spatial knowledge in a VE. It demonstrates that little is known or understood about the phenomenon of presence. We still do not know the full importance of presence in VEs, however we can clearly see that the effects of presence can be counterintuitive when relating presence to performance. A quantitative measure for presence has yet to emerge, although this area has been studied in depth. What should future research focus on in its attempt to study presence?

Future research should explore the effects of proprioception and its effect on presence and performance more thoroughly. Further, an examination of all the effects of presence on acquiring knowledge in VEs would be useful. Examples should be, but are not limited to, distance estimation tasks, various exposure times, and training transfer aspects resulting from presence.

Another area that needs to be examined is the comparison of an egocentric point of view and exocentric point of view and the related effects of presence in VEs. Implicit in the current definitions of presence is an egocentric viewpoint. The ability to be located in a place other than where one's body is physically located suggests an egocentric viewpoint. It would be interesting to examine how an exocentric viewpoint affects a person's level of presence and its related effects on performance. It seems logical to believe that the VE viewpoint must be believable or somewhat realistic to induce a high sense of presence. This research would be relevant particularly for simulator training. For example, a flight simulator that provides the pilot a cockpit viewpoint (egocentric) as compared to the wingman viewpoint (exocentric) would be valuable to understanding presence. It seems logical to believe that the user who has the cockpit viewpoint would likely experience higher levels of presence than a user that had the exocentric viewpoint as well as more opportunities to enhance performance and transfer knowledge gained from the VE experience. Furthermore, this would also be related to proprioception research. From an egocentric viewpoint, proprioception is possible and perhaps desirable. However from the exocentric viewpoint, proprioceptive methods seem unnatural and implausible.

Another area that warrants further research would be an examination of the relationship between presence and *perceived* performance. It was interesting to note during this experiment how various sound treatments affected the level of presence, particularly how the inclusion of noise and unrelated verbal information resulted in lower levels of presence. These results are

somewhat unexplainable, however it may be that the "noise" created a sense of doubt among participants' ability to complete the various spatial tasks. An interesting study would be to examine how people perceive their performance (regardless of the actual outcome) and relate this to presence. Perhaps as people "feel" better about their performance, the more likely they are to answer questions about presence in a positive manner as compared to those who are unsure or believe they performed poorly.

This study began looking at the effect of presence on spatial performance. When we answer the questions posed here, we will be better able to build VEs that meet the needs of the users. Many of these needs currently go unfulfilled, resulting in systems that are expensive and provide less than the desired results. Our goal should be the same as Ivan Sutherland, who in 1965 described the "ultimate display" that included full-color, stereoscopic, high-resolution imagery, filling the user's entire field of view [SUTH 65]. This can be summarized as a display that appears seamless when compared to the real world, where presence is a controllable design element used to enhance performance on tasks within the VE.

This page intentionally left blank.

LIST OF REFERENCES

[BADD 78] Baddeley, A. D. and Hitch, G., "Working Memory", *Psychology of Learning and Motivation*, 8, 47-87, 1978.

[BANK 97] Banker, W.P., *Virtual Environments and Wayfinding in Natural Environemnts*, Naval Postgraduate School, Monterey, CA, 1997.

[DARK 95] Darken, R.P., *Wayfinding in Large-scale Virtual Worlds*, Department of Engineering and Computer Science, George Washington University, Washington, D.C., 1995.

[DODS 98] Dodsworth, C. *Digital Illusions; Entering the Future with High Technology*, New York, Addisen-Wesseley, 1978.

[DURL 95] Durlach, N.I., Mavor, A.S. and Committee on Virtual Reality and Development, *Virtual Reality: Scientific and Technological Challenges*, Washington, D.C., National Academy Press, 1995.

[FRAN 71] Frankel, F. and Cole, M., "Measures of Category Clustering in Free Recall", *Psychological Bulletin*, 76(1), 39-44, 1971.

[GALE 90] Gale, S., "Human Aspects of Interactive Multimedia Communication", *Interacting with Computers*, 2, 175-189, 1990.

[GILK 95] Gilkey, R.H. and Weisenberger, J.M., "The Sense of Presence for the Suddenly Deafened Adult: Implications for Virtual Environments", *Presence: Teleoperators and Virtual Environments*, 4(4), 357-363, 1995.

[GOER 98] Goerger, S., http://interact.nps.navy.mil/Navigation/ LandNavigation/ Exp_HerHall/PaperHTML/OA_Paper.html, 1997.

[GOLL 91] Golledge, R.G., *Environment Cognition and Action: An Integrated Approach,* Garling and Evans, New York, Oxford University Press, 1991.

[HEND 96] Hendrix, C. and Barfield, W., "Presence within Virtual Environments as a Function of Visual Display Parameters", *Presence: Teleoperators and Virtual Environments*, 5(3), 274-289, 1996.

[HEET 92] Heeter, C., "Being There: The Subjective Experience of Presence", *Presence: Teleoperators and Virtual Environments*, 1 (2), 262-271, 1992.

[LAWS 98] Lawson, J.P., *Level of Presence or Engagement as a Function of Disengagement from a Concurrent Experience*, Department of Computer Science, Naval Postgraduate School, Monterey, CA, 1998.

[PROT 94] Prothero, J.D., Parker, D.E., Furness III, T.A., and Wells, M.J., *Towards a More Robust, Quantitative Measure for Presence*, Seattle, Washington, University of Washington Human Interface Technology Laboratory (HITL), 1994.

[ROEN 78] Roenker, D.L., Thompson, C.P. and Brown, S.C., "Comparison Measures for the Estimation of Clustering in Free Recall", *Psychological Bulletin*, 76, (1), 45-78, 1978.

[SATA 95] Satalich, G., "*Navigation and Wayfinding in Virtual Reality: Finding the Proper Tools and Cues to Enhance Navigational Awareness*", (unpublished), http://www.hitl.washinton.edu/publications/1995Pub.html, 1995.

[SHER 92] Sheridan, T.B., "Musings on Telepresence", *Presence: Teleoperators and Virtual Environments*, 1(1) 120-126, 1992.

[SLAT 97] Slater, M. And Sylvia, W., "A Framework for Immersive Virtual Environments (FIVE): Speculations on the role of Presence in Virtual Environments", *Presence: Teleoperators and Virtual Environments*, 6(6), 603-616, 1997.

[SUTH 65] Sutherland, I.E., "The Ultimate Display", *Proceedings of the IFIPS Congress*, volume 2, pages 506-508, 1965.

[THOR 80] Thorndyke, P.W., *Performance models for Spatial and Locational Cognition (R-2676-ONR)*, Washington, D.C., The RAND Corporation, 1980.

[WALL 99] Waller, D., Hunt, E. and Knapp, D., *The Transfer of Spatial Knowledge in Virtual Environment Training,* Unpublished master's thesis, University of Washington, 1999.

[WICK 97] Wickens, C.D., Gordon, S.E., and Liu, Y., *An Introduction to Human Factors Engineering*, New York: Longman, 1998.

[WITM 98] Witmer, B.G. and Singer, M.J., "Measuring Presence in Virtual Environments: A Presence Questionnaire", *Presence: Teleoperators and Virtual Environments*, 7(3), 225-240, 1998.

BIBLIOGRAPHY

Held, R.M., and Durlach, N. I., "Telepresence", *Teleoperators and Virtual Environemnts*, 1(1), 109-112, 1992.

Hix, D. And Hartson, H.R., *Developing User Interfaces, Ensuring Usability Through Product and Process,* New York: Wiley, 1993.

Sheridan, T.B., "Musings on Telepresence," *Presence: Teleoperators and Virtual Environments*, 1(1) 120-126, 1992.

Slater, M., and Usoh, M., "Presence in Immersive Virtual Environments," *Proceedings of IEEE 1993 Virtual Reality Annual International Symposium*, 90-96, Piscataway, NJ: IEEE Service Center, 1993.

Wickens, C.D., Gordon, S.E., and Liu, Y., *An Introduction to Human Factors Engineering,* New York: Longman, 1998.

This page intentionally left blank.

APPENDIX A. RAW DATA

SUBJECT	AGE	SEX	TREAT	IT-1	IT-2	IT-3	IT-4	IT-5	IT-6	IT-7	IT-8	IT-9
1	32	M	NS	7	2	2	7	5	2	6	5	5
2	25	F	SP	5	5	3	4	6	3	3	6	6
3	30	F	P	2	4	7	7	3	1	6	1	2
4	35	M	NS	5	4	6	6	3	4	5	3	3
5	33	M	S	4	4	5	6	3	5	7	5	5
6	31	M	S	4	6	6	5	5	2	5	2	4
7	31	M	SP	2	6	3	5	5	6	6	5	6
8	46	M	P	7	6	6	6	5	5	6	5	5
9	37	M	P	6	5	5	6	6	6	7	2	3
10	30	M	S	6	6	2	6	7	5	5	3	4
11	40	M	NS	3	6	2	5	2	1	4	1	3
12	37	M	NS	7	6	4	7	4	4	7	4	2
13	31	M	SP	5	3	6	6	4	4	6	6	5
14	38	M	SP	4	6	5	4	5	5	5	4	5
15	27	F	SP	4	7	4	4	6	5	4	4	5
16	29	M	P	6	3	3	7	6	6	6	6	3
17	25	F	P	5	4	6	5	5	2	6	5	4
18	33	M	NS	6	5	5	6	6	3	6	3	4
19	32	M	NS	7	5	3	4	5	5	5	6	6
20	32	M	S	6	5	4	3	4	1	5	3	5
21	36	M	NS	6	4	2	5	5	7	5	5	5
22	34	M	P	5	5	5	7	6	5	6	3	2
23	33	M	NS	6	5	4	4	2	2	3	2	5
24	24	M	S	6	5	7	4	3	2	5	4	4
25	28	F	S	6	3	5	6	7	6	5	6	5
26	34	M	S	5	4	3	6	7	6	6	5	6
27	32	M	SP	5	6	5	5	5	5	5	5	5
28	29	F	NS	6	5	5	4	6	6	5	4	6
29	30	F	SP	6	5	4	3	5	5	3	4	5
30	32	M	SP	7	4	2	6	6	6	6	6	5
31	30	M	SP	6	3	5	6	3	6	6	4	5
32	28	M	P	7	6	1	5	5	6	6	6	5
33	36	M	P	7	6	5	6	7	7	6	6	5
34	33	M	P	5	5	6	3	5	6	5	5	4
35	31	M	P	5	5	4	6	5	4	6	4	4
36	34	M	NS	6	5	5	4	6	4	4	5	6
37	34	M	SP	7	5	5	5	3	2	5	3	3
38	30	M	S	6	4	6	5	5	5	5	5	5
39	37	M	S	5	6	4	7	4	5	7	5	4
40	40	M	S	6	7	6	7	5	2	7	5	6
41	35	M	NS	6	4	6	5	5	3	4	4	4

IT-10	IT-11	IT-12	IT-13	IT-14	IT-15	IT-16	IT-17	IT-18	IT-19*	IT-20	IT-21	IT-22	IT-23	IT-24*	IT-25
5	3	0	5	6	4	5	6	6	6	5	2	3	7	7	3
2	2	0	5	5	5	3	6	6	3	6	1	2	6	1	6
1	2	0	5	4	5	1	4	4	4	5	2	4	3	6	4
3	2	0	4	3	5	5	4	6	2	6	3	2	5	3	5
2	5	0	6	6	7	2	2	7	4	6	2	4	5	6	2
2	3	0	6	5	2	2	2	3	5	5	2	5	6	3	4
2	2	0	5	6	5	2	3	6	4	5	1	5	5	6	5
1	2	0	5	3	6	4	1	5	3	5	1	3	4	4	2
3	2	0	5	5	5	2	2	6	3	6	2	5	5	2	2
1	2	0	4	5	6	2	5	7	5	7	2	4	5	3	5
1	3	0	4	5	2	2	3	4	5	6	2	5	3	3	2
2	4	0	7	6	2	3	1	4	2	6	1	5	4	1	4
3	1	0	4	6	2	3	5	2	5	5	1	3	4	4	4
1	3	0	5	6	5	4	4	4	5	6	1	5	4	5	4
1	5	0	4	6	3	2	4	6	3	5	2	4	2	4	6
4	2	0	7	7	6	2	2	5	3	5	2	5	5	7	4
3	2	0	4	5	2	5	5	3	4	7	2	3	6	6	5
1	2	0	5	5	5	2	5	5	4	6	5	4	5	5	4
6	3	0	5	6	4	3	6	7	4	6	1	3	5	2	5
2	5	0	5	6	5	6	4	7	5	6	2	5	5	4	5
3	2	0	5	6	2	4	4	4	4	6	4	4	5	3	2
1	4	0	6	4	5	5	1	1	1	7	2	4	6	1	4
3	2	0	5	5	2	3	5	6	5	6	2	3	3	3	4
3	2	0	5	4	6	4	3	6	5	7	2	3	4	3	3
3	4	0	6	6	1	5	5	5	3	5	1	4	6	7	5
5	2	0	6	2	5	5	5	5	3	7	6	4	5	3	5
3	3	0	5	5	6	3	3	3	5	6	3	4	6	5	5
1	2	0	5	7	7	6	5	6	4	7	1	4	5	2	5
2	5	0	4	5	6	4	5	4	3	5	1	3	4	3	5
4	1	0	5	5	6	2	2	6	5	6	4	3	7	5	4
3	3	0	6	6	6	4	3	6	5	6	1	4	4	4	3
2	4	0	6	7	2	4	1	7	6	6	7	5	4	4	3
1	1	0	6	6	6	5	6	7	7	1	2	5	5	4	2
3	2	0	4	3	2	4	4	5	3	6	1	2	3	3	3
4	4	0	5	5	5	3	2	4	5	6	7	5	6	5	3
3	2	0	4	4	3	4	5	5	4	6	2	5	6	2	5
2	4	0	5	5	3	3	3	3	1	5	2	3	4	4	3
5	2	0	6	5	7	4	4	6	3	6	2	4	5	4	3
5	1	0	4	5	4	4	1	4	5	6	2	3	4	4	2
6	2	0	7	7	7	2	6	7	5	7	3	4	6	5	2
3	3	0	3	4	5	3	2	6	5	6	3	4	5	5	4

IT-26	IT-27	IT-28	IT-29	IT-30	IT-31	IT-SUM	PQ-1	PQ-2	PQ-3	PQ-4	PQ-5	PQ-6	PQ-7	PQ-8*
3	1	1	5	1	1	126	2	7	6	2	5	1	6	6
7	4	2	6	6	5	130	2	5	4	5	6	6	3	5
1	6	6	5	1	2	108	6	6	6	7	6	5	7	1
3	5	2	5	1	1	114	3	4	2	3	5	1	1	1
2	1	4	4	1	1	123	2	6	4	2	4	3	4	4
4	3	2	3	2	2	110	2	6	4	4	5	5	5	4
2	2	5	3	5	3	126	1	2	2	3	4	4	2	5
2	2	5	3	1	1	114	2	5	3	3	5	4	4	4
1	1	2	5	1	1	112	1	5	6	4	6	5	4	5
3	1	5	6	1	2	125	4	5	5	6	6	3	5	5
1	3	1	6	3	1	92	5	4	5	4	6	1	5	5
2	3	2	2	2	2	110	2	2	2	3	3	1	2	3
5	1	4	2	1	1	111	3	4	3	5	6	5	4	3
2	1	5	4	2	1	120	3	4	4	5	5	5	3	5
7	2	1	5	7	7	129	1	5	5	6	4	4	5	4
2	1	6	5	6	1	133	2	4	3	3	4	3	2	4
4	1	7	7	1	1	125	4	7	4	5	6	4	5	4
2	1	3	6	1	1	121	3	4	4	6	5	1	4	2
3	1	6	6	2	3	133	2	5	5	3	5	1	5	3
5	1	4	6	5	1	130	4	5	3	3	5	5	4	4
2	1	7	4	2	1	119	4	2	4	4	4	1	2	4
1	1	6	7	6	3	120	4	7	7	4	7	5	6	6
4	3	5	3	3	3	111	3	2	4	3	5	1	5	3
2	1	6	5	2	2	118	5	5	4	3	5	5	5	4
6	2	4	3	3	2	135	4	2	6	6	6	5	6	3
4	2	2	6	5	6	141	5	5	5	4	5	3	5	4
3	4	4	4	1	1	128	3	4	6	6	6	4	6	4
4	1	2	7	1	1	130	6	7	6	1	6	1	5	6
4	4	3	2	4	2	118	2	6	2	4	6	3	3	6
2	6	3	4	7	4	139	2	3	4	6	6	7	4	6
1	1	2	3	2	2	119	2	6	6	6	6	4	6	7
2	1	1	7	1	1	128	5	5	5	3	4	5	3	5
1	1	2	6	1	1	131	2	3	3	5	6	5	3	3
3	1	2	6	5	3	112	3	4	3	5	6	5	5	6
2	2	5	4	7	2	134	3	3	4	3	4	4	3	3
3	2	4	5	2	2	123	2	2	2	3	6	1	1	5
3	3	1	3	6	5	109	5	5	5	5	6	6	5	4
3	1	1	3	2	3	125	3	3	5	5	6	4	5	3
2	1	4	5	5	1	119	2	4	2	3	5	4	2	6
2	1	7	5	2	1	145	5	6	6	5	6	7	6	3
2	2	3	4	1	1	115	1	3	5	5	5	1	4	3

PQ-9*	PQ-10	PQ-11*	PQ-12	PQ-13	PQ-14	PQ-15	PQ-16	PQ-17	PQ-18	PQ-19	PQ-20	PQ-21	PQ-22	PQ-23	PQ-24*
2	6	1	6	7	6	1	1	1	7	5	1	1	2	6	7
5	5	4	4	3	5	6	5	1	4	4	4	1	1	4	5
4	7	2	6	6	7	4	5	1	6	4	4	1	4	6	7
2	4	1	5	4	4	1	1	1	4	3	1	1	5	3	2
3	4	4	2	6	5	2	2	1	4	4	4	1	2	5	7
4	6	5	3	6	3	5	3	1	5	3	2	2	6	5	6
3	5	6	3	6	5	7	5	1	5	2	4	1	1	5	5
3	4	4	5	4	4	4	2	1	4	3	3	1	3	4	5
2	5	5	4	4	5	3	3	1	5	3	5	1	2	5	6
2	6	6	3	6	6	3	3	1	6	3	4	3	3	6	6
2	5	5	1	5	4	1	1	1	4	4	5	1	1	6	7
3	4	5	7	2	2	1	1	4	2	3	2	3	2	4	5
2	5	3	2	2	3	3	3	4	5	2	3	1	1	4	6
3	3	3	5	6	2	6	3	1	6	3	4	1	4	6	6
3	4	5	5	5	6	5	2	1	6	5	5	1	4	4	6
4	4	5	3	5	4	2	2	1	3	2	2	2	4	4	4
4	5	3	3	7	6	5	4	1	5	4	4	2	6	5	6
3	5	5	4	4	4	1	1	1	4	3	4	3	1	6	4
2	6	5	3	6	6	1	1	6	6	2	5	1	5	5	7
4	4	4	5	5	5	4	3	3	4	3	4	4	4	5	6
3	5	4	2	2	6	1	1	1	6	2	5	2	3	4	6
1	6	7	2	7	6	7	1	1	4	2	4	1	1	4	7
3	5	3	5	5	5	1	1	1	5	4	2	1	1	4	6
3	4	4	5	4	3	3	4	1	4	3	4	3	4	5	4
3	4	5	3	4	6	4	3	1	5	4	5	4	5	6	6
4	5	5	6	6	5	3	4	3	5	5	5	4	2	5	5
3	6	5	3	5	5	4	4	1	6	5	6	1	2	5	7
1	6	2	7	5	6	1	1	1	6	4	5	1	1	7	7
3	5	2	6	2	5	5	4	5	4	2	3	4	2	4	6
2	5	6	2	7	4	6	6	5	5	5	4	1	3	6	5
4	6	6	6	2	6	5	4	5	6	5	6	5	2	6	6
4	4	4	4	4	5	5	5	1	4	3	3	1	4	5	4
3	5	6	2	4	3	7	7	5	5	5	6	1	6	6	3
6	5	5	4	5	6	5	3	1	4	2	3	1	2	3	6
4	5	3	5	6	4	3	4	1	5	3	5	2	2	4	5
3	5	7	6	6	2	1	1	1	7	4	4	1	3	5	2
3	4	4	4	3	5	7	5	3	3	3	4	3	3	5	5
3	6	4	5	4	6	2	3	2	5	5	6	5	3	5	4
2	4	4	4	6	4	2	1	4	4	3	4	2	4	6	3
1	6	6	6	7	6	2	1	1	6	3	5	1	1	6	6
3	4	5	4	7	5	1	1	1	4	3	4	2	1	4	7

PQ-25*	PQ-26	PQ-27	PQ-28*	PQ-29*	PQ-30	PQ-31	PQ-32	PQ-SUM	Con. Respond.	Sen. Expl.	Involve.
6	7	7	4	6	6	2	6	139	46	37	39
5	5	3	3	5	4	3	5	130	35	31	32
6	7	4	5	7	7	1	3	158	50	42	34
6	3	5	6	3	4	1	2	92	28	23	26
7	3	3	3	7	7	2	3	120	42	26	25
6	6	6	6	6	6	2	3	141	40	32	32
6	7	6	3	6	6	2	3	126	32	33	28
4	4	3	3	4	5	3	2	112	33	25	27
3	6	5	5	6	6	5	7	138	36	37	37
5	6	6	6	6	7	5	6	153	45	42	38
4	7	7	2	7	7	5	6	133	41	37	31
4	4	2	5	4	5	1	1	94	24	20	27
3	5	5	2	4	5	3	4	113	27	30	26
4	5	5	2	7	7	4	3	133	32	32	29
5	4	5	6	6	5	2	1	135	42	38	28
4	4	3	4	4	4	4	4	107	31	24	27
7	3	5	6	7	6	2	6	151	47	34	35
5	5	4	3	5	4	4	6	118	36	34	31
3	5	6	4	7	7	5	6	139	39	37	32
4	6	4	4	6	6	4	5	139	37	33	32
5	4	6	7	7	6	2	1	116	31	37	27
7	7	7	7	7	7	1	1	151	53	40	33
2	6	3	5	5	4	2	4	109	33	29	31
7	5	4	3	4	6	5	5	133	40	30	31
3	6	6	6	6	6	4	5	148	40	44	33
7	6	5	6	6	6	4	3	151	48	39	34
5	6	6	6	6	5	3	3	147	44	42	33
6	7	7	7	7	7	1	4	145	47	39	43
6	3	2	3	6	5	1	6	126	30	27	36
3	5	5	5	6	6	1	7	148	38	34	37
7	6	6	6	6	7	3	5	169	46	47	42
4	4	4	4	5	4	4	5	129	38	29	31
1	4	2	2	7	6	4	6	136	30	29	30
5	5	5	6	6	6	5	2	138	38	32	32
4	6	5	4	5	6	3	5	126	33	34	30
2	7	6	5	3	4	2	1	110	28	32	33
5	5	5	4	4	5	4	3	140	40	35	30
4	6	5	6	6	6	4	6	145	39	43	37
3	7	6	3	3	6	4	7	124	30	32	35
6	7	7	6	6	7	1	6	154	51	43	39
5	4	4	4	5	7	1	2	115	38	33	26

Inter. Aware	Con Distract	selection score	Orientation-1	Lake Pluto	Moving Co	Mobil1
20	29	7	North East	0	0	3
15	20	9	East	4	4	1
22	33	7	North West	4	0	3
10	16	7	West	4	4	0
22	28	8	South	4	2	0
20	29	8	East	4	4	4
18	22	10	East	4	4	1
15	21	8	North	4	0	1
19	27	9	West	4	2	2
22	30	10	North	4	4	4
22	28	8	East	4	4	4
17	21	6	East	4	0	0
16	21	9	North	4	2	1
21	25	9	East	4	4	2
18	28	8	East	4	4	2
14	18	8	East	4	0	1
21	30	9	East	4	1	1
16	20	9	East	4	3	1
22	30	7	North	4	4	4
22	26	10	West	4	3	3
21	28	9	West	4	3	1
22	34	8	North	4	1	1
16	25	6	North	4	1	1
17	22	10	North	4	4	4
22	30	7	East	4	4	3
21	28	10	East	4	4	4
19	30	10	East	4	4	4
22	33	8	North	0	4	1
21	23	8	North	4	2	1
18	26	6	East	4	0	2
24	31	9	East	4	2	1
14	20	7	East	4	0	1
17	21	8	East	4	0	1
19	29	7	East	4	4	1
18	23	9	East	4	4	4
10	15	7	East	4	3	0
17	23	9	North	4	4	1
21	27	8	East	4	1	0
14	17	8	North	4	3	2
20	31	8	North	4	4	1
21	27	10	East	4	4	4

Mobil2	Drug Store	Roman Church	7-11A	7-11B	Tower	7-11C	SCORE-MAP1	MAP1-PERCENT
4	3	0	4	2	2	2	20/28	71.4%
1	4	4	1	1	3	0	23/36	63.9%
4	0	1	2	0	1	4	19/28	67.9%
3	0	1	1	1	0	4	18/28	64.3%
1	0	1	2	1	1	1	13/32	40.6%
1	0	1	0	1	1	1	17/32	53.1%
4	4	1	4	2	2	2	28/40	70.0%
1	1	1	1	1	1	0	11/32	34.4%
4	0	1	1	1	1	1	17/36	47.2%
4	4	4	1	1	2	1	29/40	72.5%
4	0	1	1	1	1	1	21/32	58.3%
1	0	1	0	1	2	1	10/24	41.7%
1	3	1	2	1	1	0	16/36	44.4%
4	0	4	1	1	1	1	22/36	61.1%
4	0	0	4	3	3	1	25/32	81.3%
1	1	1	1	1	1	0	11/32	34.4%
1	0	1	1	1	1	1	12/36	33.3%
1	1	1	2	1	1	0	15/36	41.7%
4	0	0	4	0	3	4	27/28	96.4%
2	1	1	1	1	2	4	22/40	55.0%
1	3	0	2	1	3	2	20/36	55.6%
1	0	1	2	1	1	0	12/32	37.5%
0	0	0	1	1	2	0	10/24	41.7%
4	4	4	4	2	4	1	35/40	87.5%
4	0	0	1	1	1	0	18/28	64.3%
1	4	1	1	1	1	1	22/40	55.0%
2	1	1	1	1	1	1	20/40	50.0%
1	0	1	2	1	1	1	12/32	37.5%
1	0	2	1	1	2	0	14/32	43.8%
4	0	0	4	0	2	1	17/24	70.8%
1	1	1	4	0	1	2	17/36	47.2%
1	1	0	0	1	1	3	12/28	42.9%
2	0	1	1	1	1	1	12/32	37.5%
4	0	1	1	0	0	1	16/28	57.1%
4	0	4	4	1	1	2	28/36	77.8%
1	0	4	4	1	0	1	18/28	64.3%
1	2	2	1	1	0	2	18/36	50.0%
1	0	1	2	1	1	1	12/32	37.5%
4	0	0	1	1	1	2	18/32	56.3%
1	0	0	1	4	1	4	20/32	62.5%
4	2	4	4	1	4	1	32/40	80.0%

selection score-b	Orientation-2	Lake Pluto-b	Moving Co-b	Mobil1-b	Mobil2-b	Drug Store-b
10	East	4	4	4	4	4
10	East	4	4	4	4	4
10	East	4	4	4	2	2
10	East	4	4	2	1	1
9	East	4	4	1	4	2
9	North	4	1	4	4	4
10	West	4	4	4	4	4
9	West	4	4	1	2	1
0	North	4	4	1	1	1
8	North	4	1	1	1	0
10	North	4	4	4	4	4
10	North	4	1	4	4	2
10	East	4	4	4	4	4
10	North	4	4	4	4	4
9	North	4	4	1	1	0
9	North	1	2	2	2	2
10	East	4	1	4	4	2
10	East	4	1	1	4	1
10	East	4	4	4	1	2
10	East	4	4	1	1	1
10	East	4	4	4	4	4
9	East	4	4	4	4	0
10	East	4	4	4	4	4
9	East	4	4	4	2	4
9	East	4	4	3	4	0
10	North	4	1	2	4	4
10	North	4	4	1	4	4
10	East	4	4	2	4	4

Roman Church-b	7-11A-b	7-11B-b	Tower-b	7-11C-b	SCORE-MAP2	MAP2-PERCENT	PT1-1
							170
							235
							136
							150
							290
							142
							110
							115
							242
							160
							231
							140
							210
4	1	1	2	1	29/40	72.5%	187
4	4	1	2	1	32/40	80.0%	235
2	1	1	2	4	26/40	65.0%	192
4	1	1	1	4	23/40	57.5%	225
1	1	1	1	0	19/36	52.8%	230
4	4	0	1	4	30/36	83.3%	160
4	2	1	1	4	32/40	80.0%	140
0	4	2	2	1	21/36	58.3%	273
1	1	0	1	4	18/36	50.0%	348
2	1	1	1	0	12/32	37.5%	225
4	4	4	4	4	40/40	100.0%	142
1	1	2	1	1	21/40	52.5%	275
4	1	4	4	4	37/40	92.5%	115
4	1	1	2	4	32/40	80.0%	115
4	2	1	1	1	19/36	52.8%	133
2	1	1	0	2	15/36	41.7%	270
4	1	4	1	1	26/40	65.0%	265
4	4	4	1	4	28/40	70.0%	200
3	1	1	1	1	22/40	55.0%	161
1	1	1	1	1	16/40	40.0%	80
4	4	4	4	4	40/40	100.0%	157
4	4	4	4	4	36/36	100.0%	125
2	4	4	4	4	38/40	95.0%	128
4	4	4	0	4	34/36	94.4%	142
4	4	1	1	1	26/36	72.2%	300
4	4	1	4	2	30/40	75.0%	135
4	4	4	1	4	34/40	85.0%	141
4	4	4	4	4	38/40	95.0%	162

PT1-2	PT1-3	PT1-4	PT1-5	PT1-6	PT1-7	PT1-8	PT1-9	PT1-10
215	245	110	35	140	210	300	140	20
160	243	215	65	140	45	317	25	333
187	230	112	318	135	198	277	110	39
195	254	127	210	185	75	184	70	0
210	85	120	95	135	120	320	130	100
260	300	185	22	115	280	10	240	10
145	226	70	65	150	230	280	160	103
173	247	118	28	137	126	307	59	11
180	273	104	39	178	220	290	134	47
210	273	162	60	125	225	286	195	63
173	273	160	10	148	73	319	109	20
157	216	132	88	129	250	306	138	201
275	330	140	40	110	110	230	60	50
186	257	123	18	130	30	35	350	335
208	270	185	38	130	130	295	70	18
178	245	148	30	130	0	175	341	339
185	273	140	55	165	55	250	15	315
195	260	170	28	120	300	120	275	310
186	240	90	318	105	120	293	105	35
213	280	93	35	130	45	273	32	46
236	269	48	30	86	97	293	215	325
250	215	137	62	122	293	202	276	296
110	320	75	55	108	120	298	35	60
185	270	111	28	135	185	277	128	40
185	123	90	247	132	190	52	145	52
185	268	250	25	150	35	290	28	333
253	214	105	38	135	153	293	93	35
200	230	175	27	113	225	283	120	30
190	78	110	185	110	113	245	117	110
247	275	108	55	85	55	250	327	317
183	244	97	35	115	277	255	235	90
220	213	134	300	95	281	33	290	312
115	167	177	22	100	139	317	47	28
187	260	125	45	133	208	293	120	45
187	258	110	25	96	145	282	95	15
224	263	83	25	115	191	285	119	60
164	263	112	39	125	324	35	310	60
144	263	72	48	110	291	275	247	71
175	250	90	20	90	190	275	90	350
195	273	136	28	142	224	285	208	55
187	255	115	45	132	197	279	134	40

PT1-11	PT1-12	DELTA1 -1	DELTA1 -2	DELTA1 -3	DELTA1 -4	DELTA1 -5	DELTA1 -6	DELTA1 -7
70	335	28	14	20	3	6	2	14
347	10	93	41	22	102	24	2	151
66	359	6	14	35	1	83	7	2
10	5	8	6	11	14	169	43	121
50	40	148	9	180	7	54	7	76
35	359	0	59	35	72	19	27	84
108	2	32	56	39	43	24	8	34
62	353	27	28	18	5	13	5	70
89	358	100	21	8	9	2	36	24
80	356	18	9	8	49	19	17	29
353	359	89	28	8	47	31	6	123
345	358	2	44	49	19	47	13	54
90	351	68	74	65	27	1	32	86
345	358	45	15	8	10	23	12	166
45	358	93	7	5	72	3	12	66
352	8	50	23	20	35	11	12	164
5	357	83	16	8	27	14	23	141
0	320	88	6	5	57	13	22	104
45	355	18	15	25	23	83	37	76
58	358	2	12	15	20	6	12	151
310	359	131	35	4	65	11	56	99
324	338	154	49	50	24	21	20	97
80	355	83	91	55	38	14	34	76
70	359	0	16	5	2	13	7	11
125	358	133	16	142	23	154	10	6
35	359	27	16	3	137	16	8	161
57	358	27	52	51	8	3	7	43
80	357	9	1	35	62	14	29	29
98	30	128	11	173	3	144	32	83
335	359	123	46	10	5	14	57	141
158	358	58	18	21	16	6	27	81
315	358	19	19	52	21	101	47	85
61	345	62	86	98	64	19	42	57
85	5	15	14	5	12	4	9	12
47	359	17	14	7	3	16	46	51
85	359	14	23	2	30	16	27	5
97	353	0	37	2	1	2	17	128
275	356	158	57	2	41	7	32	95
65	360	7	26	15	23	21	52	6
90	360	1	6	8	23	13	0	28
67	360	20	14	10	2	4	10	1

DELTA1 -8	DELTA1 -9	DELTA1 -10	DELTA1 -11	DELTA1 -12	PT1-HITS	PT1-DEGREE-DIFF	PT2-1	PT2-2
19	11	2	15	18	7	13		
36	104	45	68	17	1	59		
4	19	21	11	6	7	17		
97	59	18	45	12	5	50		
39	1	82	5	47	5	55		
89	111	8	20	6	3	44		
1	31	85	53	9	3	35		
26	70	7	7	0	6	23		
9	5	29	34	5	6	24		
5	66	45	25	3	4	24		
38	20	2	62	6	4	38		
25	9	177	70	5	4	43		
51	69	32	35	2	2	45		
114	139	43	70	5	5	54	180	178
14	59	0	10	5	8	29	253	185
106	148	39	63	15	3	57	120	165
31	114	63	50	4	3	48	150	188
161	146	68	55	33	3	63	110	175
12	24	17	10	2	4	29	110	180
8	97	28	3	5	8	30	133	195
12	86	53	105	6	4	55	215	192
79	147	82	91	15	1	69	268	218
17	94	42	25	2	2	48	240	100
4	1	22	15	6	10	9	130	187
131	16	34	70	5	4	62	140	185
9	101	45	20	6	5	46	139	197
12	36	17	2	5	6	22	122	163
2	9	12	25	4	7	19	210	190
36	12	92	43	37	3	66	265	315
31	162	61	80	6	4	61	267	235
26	106	72	103	5	2	45	100	168
112	161	66	100	5	1	66	183	206
36	82	10	6	8	3	48	90	105
12	9	27	30	12	10	13	135	180
1	34	3	8	6	7	17	113	185
4	10	42	30	6	6	17	142	204
114	179	42	42	0	5	47	145	178
6	118	53	140	3	4	59	89	128
6	39	28	10	7	6	20	130	185
4	79	37	35	7	7	20	142	215
2	5	22	12	7	10	9	150	196

PT2-3	PT2-4	PT2-5	PT2-6	PT2-7	PT2-8	PT2-9	PT2-10	PT2-11
245	128	18	113	121	273	54	12	73
295	235	340	120	110	305	75	32	55
255	115	35	136	80	200	15	10	45
270	148	30	111	153	288	78	336	15
250	170	90	120	80	270	0	312	70
260	90	42	105	150	283	93	47	70
261	80	38	110	210	275	123	70	90
270	125	25	118	154	293	51	18	48
0	180	40	96	275	15	230	40	65
65	70	30	127	70	255	60	75	80
270	117	42	135	190	275	135	41	67
270	95	273	116	308	289	63	30	40
256	135	22	126	108	285	38	348	44
233	74	317	115	195	295	140	46	122
272	203	65	127	223	283	138	38	75
25	65	35	108	135	240	95	135	240
277	120	53	115	50	282	245	315	355
262	77	20	115	270	300	250	33	90
235	117	300	112	113	215	78	92	80
245	93	23	97	48	257	26	23	49
270	123	42	141	185	282	112	55	86
258	95	28	95	193	280	100	15	55
253	109	39	121	225	285	150	48	70
259	109	33	150	333	33	320	77	113
246	70	42	119	61	249	60	77	90
245	110	25	110	190	275	125	30	70
271	132	23	176	193	280	119	38	75
270	129	29	155	190	283	152	43	80

PT2-12	DELTA2 -1	DELTA2 -2	DELTA2 -3	DELTA2 -4	DELTA2 -5	DELTA2 -6	DELTA2 -7	DELTA2 -8
358	38	23	20	15	23	29	75	8
258	111	16	30	122	61	22	86	24
358	22	36	10	2	6	6	116	81
357	8	13	5	35	11	31	43	7
353	32	26	15	57	49	22	116	11
355	32	21	5	23	1	37	46	2
358	9	6	4	33	3	32	14	6
357	73	9	5	12	16	24	42	12
30	126	17	95	67	1	46	79	94
349	98	101	160	43	11	15	126	26
358	12	14	5	4	1	7	6	6
358	2	16	5	18	128	26	112	8
358	3	4	9	22	19	16	88	4
20	20	38	32	39	84	27	1	14
350	68	11	7	90	24	15	27	2
95	100	135	358	48	6	34	61	41
359	125	34	12	7	12	27	146	1
358	42	33	3	36	21	27	74	19
359	41	5	30	4	101	30	83	66
359	52	96	20	20	18	45	148	24
5	7	21	5	10	1	1	11	1
359	29	16	7	18	13	47	3	1
359	0	3	12	4	2	21	29	4
359	3	23	6	4	8	8	137	112
358	53	73	19	43	1	23	135	32
360	12	16	20	3	16	32	6	6
360	0	14	6	19	18	34	3	1
360	8	5	5	16	12	13	6	2

DELTA2 -9	DELTA2 -10	DELTA2 -11	DELTA2 -12	PT2-HITS	PT2-DEGREE-DIFF	BM-1	BM-2	BM-3
					0	A	A	A
					0	A	A	A
					0	A	A	A
					0	A	A	A
					0	A	A	A
					0	A	A	A
					0	A	A	B
					0		A	A
					0	A	B	A
					0	A	A	A
					0	A	A	A
					0	A	A	A
					0	A	B	A
75	6	18	5	5	28	B	A	A
54	14	0	95	2	53	A	A	A
114	8	10	5	7	35	A	A	A
51	42	40	4	6	24	D	A	A
129	66	15	0	4	45	A	A	A
36	29	15	2	5	21	A	A	A
6	52	35	5	8	17	A	A	A
78	0	7	4	7	24	A	A	A
101	22	10	37	2	58	A	A	A
69	57	25	4	3	61	A		A
6	23	12	5	11	8	A	A	A
66	12	15	5	6	34	A	A	A
91	30	11	5	6	25	A	A	A
11	28	67	27	3	32	A	B	A
9	20	20	3	6	25	A	A	A
34	117	175	75	1	99	B	A	A
116	63	60	6	5	51	A	A	A
121	15	35	5	3	36	A	A	A
51	74	25	6	3	43	A	A	A
103	5	6	6	3	45	A	A	A
17	37	31	12	8	13	A	A	A
29	3	0	6	7	14	D	A	A
21	30	15	6	8	12	A	A	A
169	59	58	6	6	49	A	A	A
69	59	35	5	2	46	A	B	A
4	12	15	7	8	12	B	A	A
10	20	20	7	7	13	A	A	A
23	25	25	7	8	12	A	A	A

BM-4	BM-5	BM-6	BM-7	BM-8	BM-9	BM-10	BM-11	BM-12
A	C	C	E	C	D	C	B	A
A	C	C	**B**	C	D	C	**E**	**E**
A	C	C	E	C	D	C	B	A
A	C	C	E	C	D	C	B	A
A	C	C	E	C	**C**	C	B	**E**
B	C	C	E	C	D	C	**E**	**E**
A	C	C	E	C	D	C	B	A
A	C	C	E	**B**	D	C	B	A
A	C	C	E	C	D	C	B	A
A	C	C	E	C	**C**	C	B	A
A	C	C	E	C	D	C	B	**E**
A	**D**	C	E	**B**	D	C		A
A	C	C	E	**A**	D	C	B	A
A	C	C	E	**E**	D	C	B	A
A	C	C	E	C	D	C	B	A
A	C	C	E	C	D	C	B	A
A	C	C	E	**A**	**C**	C	B	**E**
A	C	C	E	C	**B**	C	**A**	**E**
A	C	C	E	**E**	D	C	B	A
A	C	C	E	C	D	C	B	A
A	C	C	E	C	D	C	B	A
A	C	C	E	C	**C**	C	B	**E**
B	C		**A**	C	D	C	E	**E**
A	C	C	E	C	D	C	B	A
A	C	C	E	**B**	D	C	B	A
A	C	**A**	E	**B**	D	C	B	A
D	C	C		C	D	C	B	A
A	**D**	C	E	C	**C**	C	B	A
A	C	C	E	**E**	**C**	C	**E**	A
A	C	C	E	**E**	D	C	B	A
A	C	C	E	C	D	C	B	A
	C		E	**B**	D		**E**	
A	C	C	E	C	**C**	C	B	A
C	**D**	C	**B**	C	D	C	**E**	**E**
A	C	C	E	C	D	C	B	A
A	C	C	E	C	D	C	B	**E**
A	C	C	E	C	D	C	**E**	A
A	C	C	E	**B**	D	C	B	A
A	C	C	E	C	**C**	C	B	A
A	C	C	E	C	D	C	B	A
A	C	C	E	C	D	C	B	A

BM-13	BM-14	BM-15	BM-16	BM-17	BM-18	BM-19	BM-20	BM-21
D	D	B	D	E	D	B	B	B
D	D	B	D	E	D	B	**C**	B
D	D	B	D	E	D	B	**C**	B
D	D	B	D	E	D	B	B	B
D	D	B	**B**	E	**B**	D	**D**	B
D	**A**	B	D	E	D	B	B	B
D	D	B	D	E	D	B	B	B
D	D	B	D	E	D	B		B
B	D	B	D	E	D	B	B	B
D	D	B	D	E	D	B	B	B
D	D	B	D	E	D	B	B	B
D	D	B	D	E	D	B	B	B
D	D	B	D	E	D	B	**A**	**C**
D	D	B	D	E	D	B	B	B
D	D	B	D	E		B	B	B
D	D	B	D	E	D	B	B	B
D	D	B	D	E	D	**A**	B	**C**
D	D	B	**C**	**D**	D	B	**C**	**C**
D	D	B	D	E	D	B		
D	D	B	D	E	D	B	B	B
D	D	B	D	E	D	B	B	B
D	D	B	D	**D**	D	B	B	B
D	D	B	D	**C**	D	B	B	**C**
D	D	B	D	E	D	B	**C**	B
D	D	B	D	E	D	B	B	B
D	**C**	B	D	E	D	**C**	**A**	B
D	D	B	D	E	D	B	**C**	B
D	D	B	D	E	**E**	B	**C**	**C**
D	D	B	D	E	D	B	B	**C**
D	D	B	D	E	D	B	B	B
D	D	B	D	E	D	B	B	B
B		B	D	E	D	**D**		**E**
D	**B**	B	D	E	D	**C**	B	**C**
D	**A**	B	D	E	D	B		B
D	D	B	D	E	D	B	B	B
D	D	B	D	E	D	B	**C**	**C**
D	D	B	D	E	D	B	B	**E**
D	D	B	D	E	D	B	B	B
D	D	B	D	E	D	B	B	**C**
C	D	B	D	E	D	B	B	B
D	D	B	D	E	D	B	B	B

BM-22	BM-23	BM-24	BM-right/answered	BM-PERCENT	G-8	G-9	G-10
B	A	E	24/24	100.0%	D	A	E
B	B	E	19/24	79.2%	D	B	E
B	A	E	23/24	95.8%	D	A	B
D	A	E	23/24	95.8%	D	A	E
B	B	E	18/24	75.0%	D	A	D
B	A	E	20/24	83.3%	D	A	E
B	A	D	22/24	91.7%	D	A	E
		E	19/20	95.0%	D	A	E
B	A	E	22/24	91.7%	D	A	E
C	A	E	22/24	91.7%	D	A	D
B	A	E	23/24	95.8%	D	A	E
B	A	E	21/23	91.3%	D	A	E
B	A	E	20/24	83.3%	D	A	E
B	A	E	22/24	91.7%	C	A	E
C	A	D	21/23	91.3%	D	A	B
B	A	E	24/24	100.0%	D	A	E
B	A	E	18/24	75.0%	D	A	E
A	A	E	16/24	66.7%	D	A	E
B	A	E	21/22	95.5%	D	A	E
B	A	E	24/24	100.0%	D	A	E
B	A	E	24/24	100.0%	D	A	E
D	A	E	20/24	83.3%	C	A	E
B	A	E	16/22	72.7%	D	A	E
B	A	E	23/24	95.8%	D	A	E
D	A	E	22/24	91.7%	D	A	D
B	B	E	18/24	75.0%	A	D	D
D	C	C	17/23	73.9%	D	A	E
B	D	B	17/24	70.8%	D	A	E
D	A	E	18/24	75.0%	D	A	D
B	A	E	23/24	95.8%	C	A	E
B	A	E	24/24	100.0%	D	A	E
		E	11/16	68.8%	D	A	B
B	A	E	20/24	83.3%	D	A	E
D	E	E	15/23	65.2%	D	A	E
B	A	E	23/24	95.8%	D	A	E
A	B	E	19/24	79.2%	D	A	E
B	C	D	20/24	83.3%	C	A	B
B	A	E	22/24	91.7%	D	A	E
B	A	E	21/24	87.5%	D	A	E
B	A	E	34/24	141.7%	D	A	E
B	A	B	23/24	95.8%	D	A	E

G-11	G-12	G-13	G-14	G-15	G-16	G-17	G-18	G-19
B	B	A	C	E	B	D	B	E
B	B	A	C	E	A	D	D	E
B	B	A	C	E	B	D	B	D
B	B	A	C	E	A	D	B	E
D	B	A	D					
B	B	A	C	E	B	D	D	E
B	B	A	B	C	A	D	B	E
B	B	A	C	E	B	D	B	E
B	B	A	C	E	A	D	B	E
B	B	A	C	E	B	D	B	E
B	B	A	C	E	B	D	D	E
B	B	A	C	E	A	D	B	E
B	B	A	C	E	B	D	D	E
C	B	A	D	E	A	D	A	E
B	B	A	C	E	A	A	D	A
B	B	A	C	E	A	D	A	E
B	E	A	C	E	C	D	E	D
B	B	A	C	E	B	D	D	E
B	B	A	A	E	B	D	D	E
B	B	A	A	E	D	D	D	E
B	B	A	C	E	B	D	B	E
B	B	A	C	E	A	D	B	E
B	B	A	C	E	B	D	E	E
B	B	A	B	E	B	D	B	E
B	B	A	C	E	A	C	B	E
B	B	C	C	E	B	D	B	E
D	B	A	C	E	A	D	B	E
B	B	A	C	E	B	D	B	E
B	B	A	A	E	B	D	B	D
B	B	A	C	E	B	D	B	E
B	B	C	C	E	A	D	B	D
B	B	A	C	E	D	D	B	E
B	C	C	E	E	A	D	B	E
B	B	A	C	E	B	D	B	E
B	B	A	C	E	B	D	D	D
B	B	A	C	E	B	D	B	E
C	E	A	D	E	D	D	C	D
B	B	A	C	E	B	D	B	A
B	B	A	C	E	B	D	B	E
B	B	A	C	C	A	D	B	E
B	C	A	C	E	A	D	B	E

G-20	G-21	G-22	G-23	G-24	G-25	G-26	G-27	G-28
D	B	A	**B**	D	**B**	**E**	C	B
C	B	**B**	**E**	D	**B**	D	C	**C**
A	B	**D**	**B**	D				
D	B	A	A	D	C	D	C	B
D	B	A	A	D	C	D	C	B
C	B	A	A	D	C	D	C	B
D	B	A	A	D	**D**	D	C	
D	B	**D**	A	D	**B**	D	C	B
D	B	A	A	D	C	D	C	B
C	B	**B**	A	D	C	D	C	B
D	B	**D**	A	D	C	D	C	B
D	B	A	A	D	**A**			
E	B	A	A	D	**E**	D	C	**D**
D	B							
C	B	A	A	D	C	D	C	**A**
C	**E**	A	A	D	**A**			
D	B	**D**	A	**E**	C	D	C	B
C	B	A	**B**	D	**B**	D	C	**C**
D	B	A	A	D	C	**A**	C	**C**
C	B	A	A	D	C	**A**	C	B
D	B	A	A	D	**B**	D	C	B
D	B	A	A	D	**A**	D	C	**C**
D	B	A	A	D	C	D	C	B
A	B	**D**	**B**	**E**	**B**	D	C	B
D	B	**B**	A	**C**	C			
D	B	A	**D**	D	C	D	C	B
C	**E**	A	**E**	D	**E**	**C**	C	**C**
D	B	**D**	**B**	D	C			
D	**A**	A	A	D	C	D	C	B
D	B	**D**	A	D	C	D	C	B
D	B	A	A	D	**D**	D	C	B
D	**E**	A	A	**C**	**A**	D	C	B
A	B	**D**	**B**	D	C	D	C	**A**
D	B	A	A	D	**B**	D	C	**C**
A	B	**D**	**B**	**E**	**E**	**E**	C	B
C	B	A	**C**	D	**B**	D	C	**C**
D	B	A	A	D	C	D	C	B
D	B	A	A	D	C	D	C	B
D	B	A	A	D	**A**	D	C	B

G-29	G-30	G-31	G-32	G-33	G-34	G-35	G-36	G-37
A	**C**	D	B	**B**	C	D	**B**	**D**
B	**D**	**C**	**E**	C	C	**E**	**D**	**B**
A	E							
A	**A**	D	B	C	C	D	A	C
A	**A**	**C**	B	C	C	D		
A	E	D	B	C	**D**	D		
A	**A**	D	B	C				
A								
A	E	D	B	C	C	D	A	C
A	E							
A	E	D	B	**B**	C	D	A	C
A	**C**	D	B	**B**	C	**B**	A	**B**
A	E	**C**	B	C	**A**	**E**		
A	E	D	**A**	C	C	D	**B**	C
A	**A**	D	B	C	C	**E**		
A	E	**E**	B					
A	**C**							
A	E	D	B	C	C	D	A	C
C	E	D	**C**	C	C	D	A	C
A	E	D	B	C	C	D	A	C
B	E	D	B	C	C	D	**B**	C
A	E	**A**	B	**E**				
A	E	D	B	C	C	D	**B**	**B**
A	**A**	D	B	C	C	D		
A	**D**	**B**	B	**B**				
A	A	C	**E**	C	C	**E**		
A	E	D	B	C	C	D	A	C
A	E	D	B	C	C	D	A	C

G-38	G-39	G-40	G-41	G-42	G-43	G-44	G-45	G-46
A	D							
A	E	A	C	D	B	A	C	B
A	E	A						
A	D	A	C	E	E	C	C	B
A	D	C	C					
A	E	A	C					
A	E	A	C	E	B	C	E	
A	E	A	C	E	B	A		
B	E	A	B	E	B	A	C	B
A	D	A						
A	A	A	C	E	B	A	C	B
B	E	A	C	B				

G-47	G-48	G-49	G-50	G-right/answered	G-PERCENT
				22/30	73.3%
				17/32	53.1%
				12/17	70.6%
				23/23	100.0%
				4/7	57.1%
C	D	D	D	44/52	84.6%
				23/28	82.1%
				18/20	90.0%
				19/21	90.5%
				25/28	89.3%
				21/26	80.8%
				20/21	95.2%
				15/18	83.3%
				15/22	68.2%
				10/14	71.4%
				30/33	90.9%
				11/18	61.1%
				19/23	82.6%
				27/39	69.2%
				24/34	70.6%
				22/28	78.6%
				30/34	88.2%
				24/29	82.8%
				22/25	88.0%
				15/23	65.2%
				11/18	61.1%
				28/30	93.3%
				28/38	73.7%
				12/18	66.7%
				18/21	85.7%
				34/37	91.9%
A	A	B	A	34/50	68.0%
				9/12	75.0%
				20/26	76.9%
				23/33	69.7%
				24/28	85.7%
				9/26	34.6%
				20/28	71.4%
C				37/40	85.0%
				32/35	91.4%
				19/21	90.5%

This page intentionally left blank.

APPENDIX B. EXPERIMENT OUTLINE

1. EXPERIMENT PRE-CHECK LIST

a. Unplug telephone in lab
b. Section off experiment area
c. Post "Quiet Experiment in Progress" Sign
d. Turn on power to 3 screen display and amplifier
e. Ensure audio is set up and ready
f. Ensure Flybox is on and positioned correctly
g. Ensure Pointing Test and Magnet Board Test are ready
h. Ensure table and chair is provided
i. Ensure digital camera is available and ready
j. Start experiment program (ezs_rtm_pf20_o62 –s UFO_3screen2.set –S –P3 –L)
k. Load recording F1 Key
l. Play recording PAGEDOWN/HOME Key
m. Stop recording END Key
n. Rewind recording INSERT Key
o. Welcome subject and complete consent forms
p. Administer pre-questionnaires
    1. Immersive Tendency Questionnaire (ITQ)
q. Administer Spatial Abilities Test
    1. Visual Memory Test (Building Memory Test)
    2. Guilford-Zimmerman Test
r. Escort subject to Graphics Lab
s. Ensure subjects are seated and comfortable in front of 3 screen display
t. Give subject experimental area in-brief
u. Enter subjects trial number
v. Start experiment program

2. EXPERIMENT POST-CHECK LIST

a. Rewind recording appropriately INSERT Key
b. Prepare subject for Pointing Test
c. Record data from Pointing Test
d. Remove subject from experimental area
e. Prepare subject for Magnet Board Test
    1. Initial Selection Test
    2. Map Construction Test
f. Take digital pictures of maps
g. Have subjects complete Post-questionnaires
    1. Presence Questionnaire (PQ)
h. Debrief and thank subject for participation
i. Ensure all data is recorded properly
j. Plug in telephones
k. Remove "quiet experiment in progress" sign

APPENDIX C. INBRIEFING SCRIPT

1. GENERAL

The scripts in this appendix appear in the same format as that used for the experiment. This appendix consists of the entire In Brief sequence, that is, the In Briefing prior to entering the experiment area as well as the In Briefing upon entering the experiment area. Each subject receives the entire In Brief. This appendix also contains the Debriefing handout that is provided to every subject as well.

2. IN-BRIEFING

Welcome to the Naval Postgraduate School's Computer Department. My name is David Bernatovich and I would like to thank you for your assistance with today's experiment. This experiment involves presence and the acquisition of spatial knowledge in a virtual environment.

This experiment is not a test of your performance or mental capabilities. It is, however, a test to determine the relationship between of person's level of presence in a VE and their propensity to acquire spatial knowledge from that VE. All information is confidential and will be kept in strict confidence.

Prior to getting started, I would like you to read and sign a consent form. After signing the consent form, you will take a few short tests and answer a pre-questionnaire. This should take approximately 20 minutes. Upon completion of the pre-questionnaires, you will be escorted to the Graphics Lab to go through the VE. Upon completion of the VE, you will complete several tasks based on your experience. You will then be brought back to this room to complete two more

questionnaires followed by a short debriefing. If there are no questions please read and then sign the consent form.

Before we get started let me explain the tasks you will be asked to complete after your VE experience. There will be two tasks and both are designed to determine the level of spatial knowledge that you acquired from the virtual world. First, you will be asked to complete a Pointing Test Task. This involves going back into the virtual environment and using this pointer to aim in the direction of various objects that you saw. Second, you will be asked to complete the Magnet Board Test. This involves several steps. First, you will be asked to select the buildings that you saw from this group of magnetic representations of buildings. Some you will have seen and some you will have not. Second, you will be asked to place these magnets on this rudimentary map of the virtual environment. This is the road network of the town you will be going through. You will also be asked to identify the route you took using these gray colored magnets. If you have no questions allow me to set the stage for you. You have just moved to a new town. The company that you are going to work for has set up an appointment with a realty company. The realtor uses a remote-controlled vehicle and automated tour prior to meeting with you to discuss your interests. The tour will show you the town. The tour begins just before entering the city limits and ends shortly after leaving the town. You will be cued when you enter the town (i.e. the magnet board) as well as when you leave. After the tour you will be given the tests discussed earlier. Again, if you have no further questions let's get started.

3. DEBRIEFING (upon completion of post-questionnaires outside of experiment area)

Today, virtual environments are increasingly becoming a major force in training as well as entertainment. Although the technology we use to create these virtual worlds has increased dramatically, there remain many questions relating to what is required in a VE to ensure we maximize the benefits of this type of training or experience.

The experiment you have just completed is concerned with the effect presence has on a person's ability to acquire spatial knowledge in a VE. You were provided one a four possible treatments in the VE. They were: No Sound, Presence Sound only, Spatial Information Only and both Spatial and Presence combined. This experiment is attempting to find a relationship between the level of presence and the ability to acquire spatial knowledge.

Four groups are being tested based on the treatments mentioned above. The research personnel observed and recorded information based on the VE experience in order to determine the role presence has in a person's ability to acquire spatial knowledge in a VE. The results of this study will be used to help VE developers determine what level of presence is required to optimize a person's spatial capabilities. This will allow planners to create VE that are specifically designed to meet the desired needs of the real world.

Your assistance today is greatly appreciated and will contribute to better VE construction in the future. With the information we are gathering from you and others, we are learning what is necessary to include in VEs to ensure the utility gained is maximized as well as what can be removed or is unnecessary to the user.

If you have any questions about this study please ask or E-mail me with your questions. Please do not discuss this experiment with anyone except our research personnel until 1 June 1999. This is to prevent influencing any future subjects. Thank you for participating in this study.

Additional information on this study can be obtained from David Bernatovich at 643-9323 or E-mail: bernatov@cs.nps.navy.mil.

Presence and the Acquisition of
Spatial Knowledge in Virtual
Environments

Last Name: ______________
Sequence Number: _________
Date: ___/___/____

APPENDIX D. CONSENT FORMS

1. GENERAL:

The forms in this appendix appear in the same format used for the experiment and do not follow the standard thesis format utilized in this thesis. This appendix consists of three documents: Consent Form, Minimal Risk Consent Statement, and the Privacy Act Statement. Each subject is required to read and sign these documents prior to participating in the experiment. A research monitor observes and verifies the signing of each document.

2. PARTICPANT CONSENT FORM

Spatial Awareness and Presence Experiment
CONSENT FORM

You are invited to participate in a study of presence and the acquisition of spatial knowledge in virtual environments. With data from you and other participants we hope to find out more about how people acquire spatial knowledge and how that acquisition is affected by presence in virtual environments. We ask that you read and sign this form indicating that you agree to be in the study. Please ask any questions you may have before signing.

Background information: This study is being conducted by Captain David Bernatovich.

Procedures: If you decide to participate in this study, the researchers will explain the tasks in detail. There will be an hour session. This session involves going through a virtual environment and then being asked to point in the direction of objects that you have seen. Additionally, you will be asked to place magnetic representations of the objects you saw on a metal board. The direction in which you point and the location of the objects will be recorded.

Risks and benefits of being in the study: This study has no unordinary risks beyond those encountered in your everyday workplace. The benefits to participants are that they gain experience with virtual environments and contribute to current research in human-computer interaction.

Compensation: No tangible reward will be given. A copy of the results will be available to you at the conclusion of the experiment.

Confidentiality: The records of this study will be kept private. We will not make any information publicly accessible that might make it possible to identify you as a participant.

Voluntary nature of the study: If you decide to participate, you are free to withdraw at any time without prejudice.

Contact and questions: The researcher involved in this study is Captain David Bernatovich (Spanagal Hall, rm. 267, 643-9323). You may ask any questions you have at any time. You will be given a copy of this form for your records.

Statement of consent: I have read the above information. I have asked questions and have had my questions answered. I consent to participate in the study.

____

Signature Date

____

Signature of Investigator Date

3. MINIMAL RISK CONSENT STATEMENT

NAVAL POSTGRADUATE SCHOOL, MONTEREY, CA 93943

Subject: VOLUNTARY CONSENT TO BE A RESEARCH PARTICPANT IN:
Presence and the Acquisition of Spatial Knowledge in Virtual Environments

1. I have read, understand and been provided "information for Participants" that provides the details of the below acknowledgements.

2. I understand that this project involves research. The purpose of the research, a description of the procedures to be used, identification of experimental procedures, and the duration of my participation have been provided to me.

3. I understand that this project does not involve more than minimal risk. I have been informed of any reasonable foreseeable risks or discomforts to me.

4. I have been informed of any benefits to me or to others that may reasonably be expected from the research.

5. I have signed a statement describing the extent to which confidentiality of records identifying me will be maintained.

6. I have been informed of any compensation and/or medical treatments available if injury occurs and if so, what they consist of, or where further information can be obtained.

7. I understand that my participation in this project is voluntary, refusal to participate will involve no penalty or loss of benefits to which I am otherwise entitled. I also understand that I may discontinue participation at any time without penalty or loss of benefits to which I am otherwise entitled.

8. I understand that the individual to contact should I need answers to questions about the research is Rudy Darken, Ph.D., Principal Investigator, and about my rights as a research subject or concerning a research related injury is the Modeling Virtual Environments and Simulations Chairman. A full and responsive discussion of the elements of this project and my consent has been taken.

Medical Monitor: Flight Surgeon, Naval Postgraduate School

____

Signature of Principal Investigator Date

____

Signature of Volunteer Date

____

Signature of Witness Date

4. PRIVACY ACT STATEMENT

NAVAL POSTGRADUATE SCHOOL, MONTEREY, CA 93943
PRIVACY ACT STATEMENT

1. Authority: Naval Instruction

2. Purpose: Presence and Spatial Knowledge information will be collected to enhance knowledge, or to develop tests, procedures, and equipment to improve the development and design of virtual environments.

3. Use: Presence and the acquisition of spatial information will be used for statistical analysis by the Departments of the Navy and Defense, and other U.S. Government agencies, provided this use is compatible with the purpose for which the information was gathered. Use of this information may be granted to legitimate non-government agencies or individuals by the Naval Postgraduate School in accordance with the provisions of the Freedom of Information Act.

4. Disclosure/Confidentiality

I have been assured that my privacy will be safeguarded. I will be assigned a control number which thereafter will be the only identifying entry on any research records. The principal Investigator will maintain the cross reference between name and control

a. I have been assured that my privacy will be safeguarded. I will be assigned a control number which thereafter will be the only identifying entry on any research records. The principal Investigator will maintain the cross-reference between name and control number. It will be decoded only when beneficial to me or if some circumstances, which is not apparent at this time, would make it clear that decoding would enhance the value of the research data. In all cases, the provisions of the Privacy Act Statement will be honored.

b. I understand that a record of the information contained in this Consent Statement or derived from the experiment described herein will be retained permanently at the Naval Postgraduate School or by higher authority. I voluntarily agree to its disclosure to agencies or individuals indicated in paragraph 3 and I have been informed that failure to agree to such disclosure may negate the purpose for which the experiment was conducted.

c. I also understand that disclosure of the requested information, including my Social Security Number, is voluntary.

____

Signature of Volunteer   Name, Grade/Rank (if applicable)   DOB   SSN   DATE

____

Signature of Witness   DATE

APPENDIX E. QUESTIONNAIRES AND TESTS

1. GENERAL

The items in the appendix appear in the same format utilized for the experiment and thus do not conform to the standard thesis format utilized in the chapters of this document. This appendix consists of four documents: Immersive Tendencies Questionnaire (ITQ), Guilford-Zimmerman Test, Building Memory Test and the Presence Questionnaire (PQ).

APPENDIX E-1. PRE-QUESTIONNAIRE

IMMERSIVE TENDENCY QUESTIONNAIRE

Indicate your answer by circling the appropriate number on the seven-point scale paying close attention to the particular anchors at the ends and in the middle of each new scale.

1. Do you ever get extremely involved in projects that are assigned to you by your boss or instructor, to the exclusion of other tasks?

NEVER			OCCASIONALLY			OFTEN
-3	-2	-1	0	+1	+2	+3

2. How easily can you switch your attention from a task in which you presently involved to a new task?

NOT SO EASILY			FAIRLY EASILY		QUITE EASILY	
-3	-2	-1	0	+1	+2	+3

3. How frequently do you get emotionally involved (angry, sad or happy) in the news stories you read or hear?

NEVER			OCCASIONALLY			OFTEN
-3	-2	-1	0	+1	+2	+3

4. How do you feel today?

NOT WELL				PRETTY WELL		EXCELLENT
-3	-2	-1	0	+1	+2	+3

5. Do you easily become involved in movies or TV dramas?

NEVER			OCCASIONALLY			OFTEN
-3	-2	-1	0	+1	+2	+3

6. Do you ever become so involved in a TV Program or book that people have problems getting your attention?

NEVER			OCCASIONALLY			OFTEN
-3	-2	-1	0	+1	+2	+3

7. How mentally alert do you feel at this time?

NOT ALERT				MODERATELY		FULLY ALERT
-3	-2	-1	0	+1	+2	+3

8. Do you ever become so involved in a movie that you are not aware of things going on around you?

NEVER			OCCASIONALLY			OFTEN
-3	-2	-1	0	+1	+2	+3

9. How frequently do you find yourself closely identifying with the characters in a story line?

NEVER			OCCASIONALLY			OFTEN
-3	-2	-1	0	+1	+2	+3

10. Do you ever become so involved in a video game that it is as if you are inside the game rather than moving a joy stick and watching the screen?

NEVER			OCCASIONALLY			OFTEN
-3	-2	-1	0	+1	+2	+3

11. On average, how many books do you read for enjoyment each month?

NONE 1 2 3 4 5 MORE

12. What kind of books do you read most frequently? (CIRCLE ONLY ONE ITEM)

Spy Novels	Fantasies	Science Fiction
Adventure Novels	Romance Novels	Historical Novels
Westerns	Mysteries	Other Fiction
Biographies	Autobiographies	Other non-Fiction

13. How physically fit do you feel today?

NOT FIT			MODERATELY		EXTREMELY FIT	
-3	-2	-1	0	+1	+2	+3

14. How good are you at blocking out external distractions when you are involved in something?

NOT VERY GOOD			SOMEWHAT			VERY GOOD
-3	-2	-1	0	+1	+2	+3

15. When watching sports, do you ever become so involved in the game that you react as if you were one of the players or a spectator at the event?

NEVER			OCCASIONALLY			OFTEN
-3	-2	-1	0	+1	+2	+3

16. Do you ever become so involved in a daydream that you are not aware of things happening around you?

NEVER			OCCASIONALLY			OFTEN
-3	-2	-1	0	+1	+2	+3

17. Do you ever have dreams that are so real that you feel disoriented when you awake?

NEVER			OCCASIONALLY			OFTEN
-3	-2	-1	0	+1	+2	+3

18. When playing sports, do you ever become so involved in the game that you lose track of time?

NEVER			OCCASIONALLY			OFTEN
-3	-2	-1	0	+1	+2	+3

19. Are you easily disturbed when working at a task?

NEVER			OCCASIONALLY			OFTEN
-3	-2	-1	0	+1	+2	+3

20. How well do you concentrate on enjoyable activities?

NOT AT ALL			MODERATELY			VERY WELL
-3	-2	-1	0	+1	+2	+3

21. How often do you play arcade or video games? (OFTEN would be at least every two days)

NEVER			OCCASIONALLY			OFTEN
-3	-2	-1	0	+1	+2	+3

22. How well do you concentrate on disagreeable tasks?

NOT AT ALL			MODERATELY			VERY WELL
-3	-2	-1	0	+1	+2	+3

23. Have you ever gotten excited during a chase or fight scene on TV or in the movies?

NEVER			OCCASIONALLY			OFTEN
-3	-2	-1	0	+1	+2	+3

24. To what extent have you dwelled on personal problems in the last 48 hours?

NOT AT ALL			SOMEWHAT			ENTIRELY
-3	-2	-1	0	+1	+2	+3

25. Have you ever gotten scared by something happening on TV or in the movies?

NEVER			OCCASIONALLY			OFTEN
-3	-2	-1	0	+1	+2	+3

26. Have you ever remained apprehensive or fearful long after watching a horror movie?

NEVER			OCCASIONALLY			OFTEN
-3	-2	-1	0	+1	+2	+3

27. Do ever avoid carnival rides because they are too scary?

NEVER			OCCASIONALLY			OFTEN
-3	-2	-1	0	+1	+2	+3

28. How often do you watch TV soap operas or documentaries?

NEVER			OCCASIONALLY			OFTEN
-3	-2	-1	0	+1	+2	+3

29. Do you ever become so involved in doing something that you lose all track of time?

NEVER			OCCASIONALLY			OFTEN
-3	-2	-1	0	+1	+2	+3

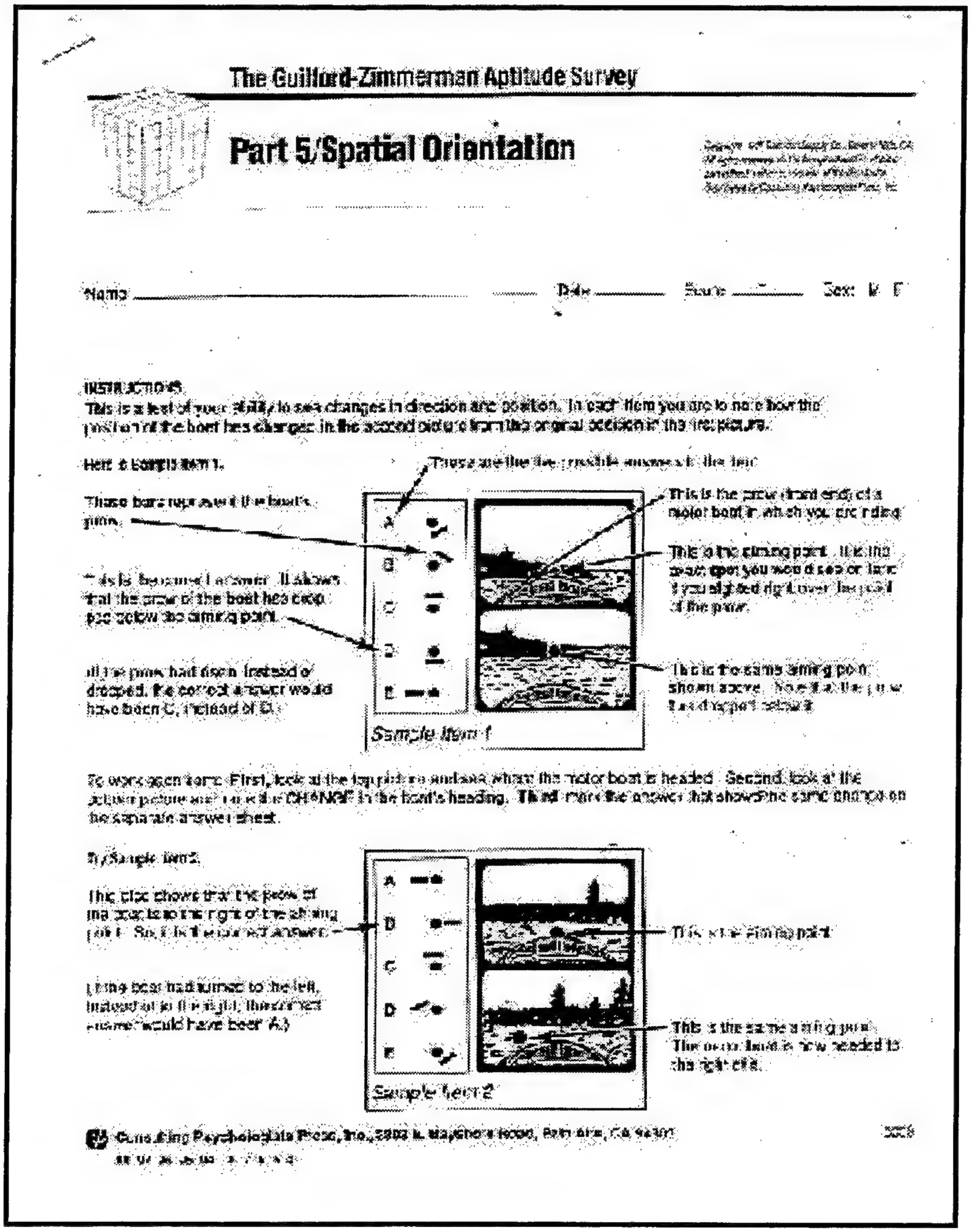
30. Do you ever get motion sickness when reading in a car?

NEVER			OCCASIONALLY			OFTEN
-3	-2	-1	0	+1	+2	+3

31. Do you ever get motion sickness when riding as a passenger in a car?

NEVER			OCCASIONALLY			OFTEN
-3	-2	-1	0	+1	+2	+3

APPENDIX E-2. GUILFORD-ZIMMERMAN TEST



The Guilford-Zimmerman Aptitude Survey

Part 5/Spatial Orientation

Name ______ Date ______ Score ______ Sex: M F

INSTRUCTIONS

This is a test of your ability to see changes in direction and position. In each item you are to note how the position of the boat has changed in the second picture from the original position in the first picture.

Here is Sample Item 1.

These are the five possible answers to the item.

These bars represent the boat's prow.

This is the prow (front end) of a motor boat in which you are riding.

This is the aiming point.

This is the correct answer. It shows that the prow of the boat has dropped below the aiming point.

This is the same aiming point shown above.

(If the prow had risen instead of dropped, the correct answer would have been C, instead of D.)

Sample Item 1

To work each item: First, look at the top picture and see where the motor boat is headed. Second, look at the bottom picture and note the CHANGE in the boat's heading. Third, mark the answer that shows the same change on the separate answer sheet.

Try Sample Item 2.

This is the aiming point.

This is the same aiming point.

(If the boat had turned to the left, instead of to the right, the correct answer would have been A.)

Sample Item 2

Consulting Psychologists Press, Inc.

Figure 27: Guilford-Zimmerman Aptitude Survey Cover Page

APPENDIX E-3. BUILDING MEMORY TEST

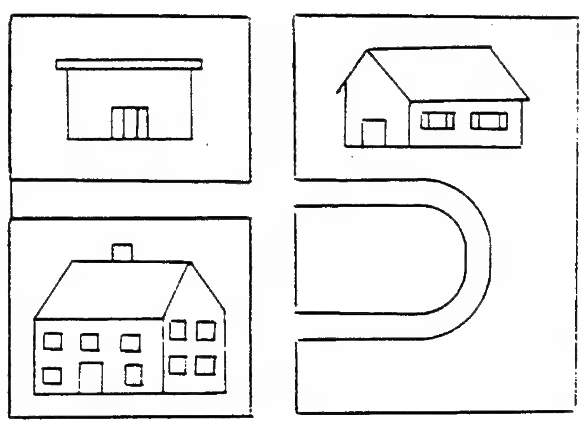
Name ____

BUILDING MEMORY — MV-2

This is a test of your ability to remember the position of things on a street map.

You will be given a map with streets and buildings and other structures to study. After you have had some time to learn the street layout and the different kinds of structures, you will be asked to turn to a test page. On that page you will find the street map and numbered pictures of some of the structures. You will be asked to put an x on the letter that shows where each of the structures was located on the study map.

Now look at this simple and enlarged sample:



After you have studied the sample above for a minute, turn to the next page.

Figure 28: Building Memory Test Cover Page

APPENDIX E-4. POST QUESTIONNAIRE

PRESENCE QUESTIONNAIRE

Characterize your experience in the virtual environment, by circling one of the appropriate numbers on the seven-point scale, in accordance with the question content and descriptive labels. Answer the questions independently in the order that they appear. Do not skip questions or return to a previous question to change your answer. ANSWER ALL QUESTIONS WITH REGARD TO YOUR EXPERIENCE IN THE EXPERIMENT.

1. How much were you able to control events?

NOT AT ALL — SOMEWHAT — COMPLETELY

-3 -2 -1 0 +1 +2 +3

2. How responsive was the environment to actions that you initiated (or performed)?

NOT RESPONSIVE — MODERATELY RESPONSIVE — COMPLETELY RESPONSIVE

-3 -2 -1 0 +1 +2 +3

3. How natural did your interactions with the environment seem?

EXTREMELY ARTIFICIAL — BORDERLINE — COMPLETELY NATURAL

-3 -2 -1 0 +1 +2 +3

4. How completely were <u>all</u> your senses engaged?

NOT ENGAGED — MILDLY ENGAGED — COMPLETELY ENGAGED

-3 -2 -1 0 +1 +2 +3

5. How much did the visual aspects of the environment involve you?

NOT AT ALL — SOMEWHAT — COMPLETELY

-3 -2 -1 0 +1 +2 +3

6. How much did the auditory aspects of the environment involve you?

NOT AT ALL — SOMEWHAT — COMPLETELY

-3 -2 -1 0 +1 +2 +3

7. How natural was the mechanism which controlled movement through the environment?

EXTREMELY ARTIFICIAL — BORDERLINE — COMPLETELY NATURAL

-3 -2 -1 0 +1 +2 +3

8. How aware were you of events occurring in the real world around you?

NOT AWARE — MILDLY AWARE — VERY AWARE

-3 -2 -1 0 +1 +2 +3

9. How aware were you of your display and control devices?

NOT AWARE MILDLY AWARE VERY AWARE

-3 -2 -1 0 +1 +2 +3

10. How compelling was your sense of objects moving through space?

NOT AT ALL MODERATELY COMPELLING VERY COMPELLING

-3 -2 -1 0 +1 +2 +3

11. How inconsistent or disconnected was the information coming from your various senses?

NOT AT ALL INCONSISTENT SOMEWHAT INCONSISTENT VERY INCONSISTENT

-3 -2 -1 0 +1 +2 +3

12. How much did your experience in the virtual environment seem consistent with your real world experiences?

NOT AT ALL INCONSISTENT SOMEWHAT INCONSISTENT VERY INCONSISTENT

-3 -2 -1 0 +1 +2 +3

13. Were you able to anticipate what would happen next in response to the actions that you performed?

NOT AT ALL SOMEWHAT COMPLETELY

-3 -2 -1 0 +1 +2 +3

14. How completely were you able to actively survey or search the environment using vision?

NOT AT ALL SOMEWHAT COMPLETELY

-3 -2 -1 0 +1 +2 +3

15. How well could you identify sounds?

NOT AT ALL SOMEWHAT COMPLETELY

-3 -2 -1 0 +1 +2 +3

16. How well could you localize sounds?

NOT AT ALL SOMEWHAT COMPLETELY

-3 -2 -1 0 +1 +2 +3

17. How completely were you able to actively survey or search the environment using touch?

NOT AT ALL SOMEWHAT COMPLETELY

-3 -2 -1 0 +1 +2 +3

18. How compelling was your sense of moving around inside the virtual environment?

NOT COMPELLING — MODERATELY COMPELLING — VERY COMPELLING

-3 -2 -1 0 +1 +2 +3

19. How closely were you able to examine objects?

NOT AT ALL — PRETTY CLOSE — VERY CLOSE

-3 -2 -1 0 +1 +2 +3

20. How well could you examine objects from multiple viewpoints?

NOT AT ALL — SOMEWHAT — EXTENSIVELY

-3 -2 -1 0 +1 +2 +3

21. How well could you move or manipulate objects in the virtual environment?

NOT AT ALL — SOMEWHAT — EXTENSIVELY

-3 -2 -1 0 +1 +2 +3

22. To what degree did you feel confused or disoriented at the beginning of breaks or at the end of the experimental session?

NOT AT ALL — MILDLY DISORIENTED — VERY DISORIENTED

-3 -2 -1 0 +1 +2 +3

23. How involved were you in the virtual environment experience?

NOT INVOLVED — MILDLY INVOLVED — VERY INVOLVED

-3 -2 -1 0 +1 +2 +3

24. How distracting was the control mechanism?

NOT DISTRACTING — MILDLY DISTRACTING — VERY DISTRACTING

-3 -2 -1 0 +1 +2 +3

25. How much delay did you experience between your actions and expected outcomes?

NO DELAYS — MODERATE DELAYS — LONG DELAYS

-3 -2 -1 0 +1 +2 +3

26. How quickly did you adjust to the virtual environment experience?

NOT AT ALL — SLOWLY — LESS THAN ONE MINUTE

-3 -2 -1 0 +1 +2 +3

27. How proficient in moving and interacting with the virtual environment did you feel at the end of the experience?

NOT PROFICIENT			REASONABLY PROFICIENT			VERY PROFICIENT
-3	-2	-1	0	+1	+2	+3

28. How much did the visual display quality interfere or distract you from performing assigned tasks or required activities?

NOT AT ALL		SOMEWHAT	INTERFERRED		PERFORMANCE	PREVENTED
-3	-2	-1	0	+1	+2	+3

29. How much did the control devices interfere with the performance of assigned tasks or with other activities?

NOT AT ALL		SOMEWHAT	INTERFERRED		GREATLY	INTERFERRED
-3	-2	-1	0	+1	+2	+3

30. How well could you concentrate on the assigned tasks or required activities rather than on mechanisms used to perform those tasks or activities?

NOT AT ALL			SOMEWHAT			COMPLETELY
-3	-2	-1	0	+1	+2	+3

31. Did you learn new techniques that enabled you to improve your performance?

NO TECHNIQUES LEARNED			LEARNED SOME TECHNIQUES			LEARNED MANY TECHNIQUES
-3	-2	-1	0	+1	+2	+3

32. Were you involved in the experimental task to the extent that you lost track of time?

NOT AT ALL			SOMEWHAT			COMPLETELY
-3	-2	-1	0	+1	+2	+3

This page intentionally left blank.

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center..2
   8725 John J. Kingman Rd., STE 0944
   Ft. Belvoir, VA 22060-6218

2. Dudley Knox Library...2
   Naval Postgraduate School
   411 Dyer Rd.
   Monterey, CA 93943-5101

3. Director, Training and Eductaion...1
   MCCDC, Code C46
   1019 Elliot Road
   Quantico, VA 22134-5027

4. Director, Marine Corps Research Center...................................2
   MCCDC, Code C40RC
   2040 Broadway Street
   Quantico, VA 22134-5107

5. Director, Studies and Analysis Division.....................................1
   MCCDC, Code C45
   3300 Russell Road
   Quantico, VA 22134-5130

6. Marine Corps Representative..1
   Naval Postgraduate School
   Code 037, Bldg. 330, IN-116
   555 Dyer Road
   Monterey, CA 93940

7. Dr. Rudy Darken...2
   Computer Science Dept., Code CS/DR
   Naval Postgraduate School
   Monterey, CA 93943-5000

8. John S. Falby..1
   Computer Science Dept., Code CS/FA
   Naval Postgraduate School
   Monterey, CA 93943-5000

9. David Bernatovich..1
   79 Morgan Avenue
   Nanticoke, PA 18634

10. Dr. Mike Zyda..1
Computer Science Dept., Code CS/ZK
Naval Postgraduate School
Monterey, CA 93943

11. Mike Macedonia..1
Chief Scientist and Technical Director
US Army STRICOM
12350 Research Parkway
Orlando, FL 32826-3276

12. Director..1
Office of Science & Innovation
OSI, MCCDC
3300 Russell Road
Quantico, VA 22134-5021

13. Dr. Russell Storms...1
404 Cana of Galilee CourtOffice of Science & Innovation
OSI, MCCDC
3300 Russell Road
Quantico, VA 22134-5021

14. Dr. Durand R. Begault..1
Mail Stop 262-2, Room 130
NASA Ames Research Center
Moffett Field, California 94035-1000 USA

15. Mr. Scott Foster...1
Aureal Semiconductor
4245 Technology Drive
Fremont, CA 94538

16. Mr. Vince Hux...1
McCune Audio Video Lighting
222 Ramona Street, Suite 1
Monterey, CA 93940

17. Dr. Dan Boger..1
Computer Science Dept., Code CS/DB
Naval Postgraduate School
Monterey, CA 93943